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Omaha District

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Water Quality Conditions in the Omaha District

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2005 Annual Report

Water Quality Conditions in the Omaha District

Prepared by:

Water Quality Unit
Water Control and Water Quality Section
Hydrologic Engineering Branch
Engineering Division
Omaha District
U.S. Army Corps of Engineers

December 2006

For Information Regarding This Document Please Contact:

U.S. Army Corps of Engineers, Omaha District

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

Page

List of Tables

Page

List of Tables (Continued)

Page

List of Figures

Page

List of Plates

Page

List of Plates (Continued)

Page

List of Plates (Continued)

Page

List of Plates (Continued)

Page

List of Plates (Continued)

Page

List of Plates (Continued)

Page

List of Plates (Continued)

Page

List of Plates (Continued)

Page

List of Plates (Continued)

Page

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1 INTRODUCTION

1.1 OMAHA DISTRICT WATER QUALITY MANAGEMENT PROGRAM

The Omaha District (District) of the U.S. Army Corps of Engineers (Corps) is implementing a Water Quality Management Program (WQMP) as part of the operation and maintenance activities associated with managing the Corps' civil works projects in the District. The WQMP addresses surface water quality management issues and adheres to the guidance and requirements specified in the Corps' Engineering Regulation – ER 1110-2-8154, "Water Quality and Environmental Management for Corps Civil Works Projects" (USACE, 1995). The following four goals have been established for the District's WQMP (USACE, 2006a):

1) Ensure that water quality, as affected by District projects and their regulation, is suitable for project purposes, existing water uses, and public health and safety, and is in compliance with applicable Federal and State water quality standards.
2) Establish and maintain a water quality monitoring and data evaluation program that facilitates the achievement of water quality management objectives, allows for the characterization of water quality conditions, and defines the influence of District projects on water quality.
3) Establish and maintain strong working partnerships and collaboration with appropriate entities within and outside the Corps regarding water quality management at District projects.
4) Document the water quality management activities of the District's Water Quality Management Program, including water quality conditions at Corps projects, to record trends, identify problems and accomplishments, and provide guidance to program and project managers.

Water quality data collection and assessment are of paramount importance to the implementation of the District's WQMP.

The annual report of water quality conditions is prepared to document and assess water quality conditions occurring at Corps civil works projects in the District. The report describes existing water quality conditions and identifies any evident surface water quality management concerns. The annual reporting of project water quality conditions is done to facilitate water quality management decisions regarding the operation and regulation of Corps projects.

1.2 CORPS CIVIL WORKS PROJECTS WITHIN THE OMAHA DISTRICT

The location of Corps civil works project areas within the District, and background information on the projects, are provided in Figure 1.1 and Table 1.1. These are the civil works projects under the purview of the District's WQMP.

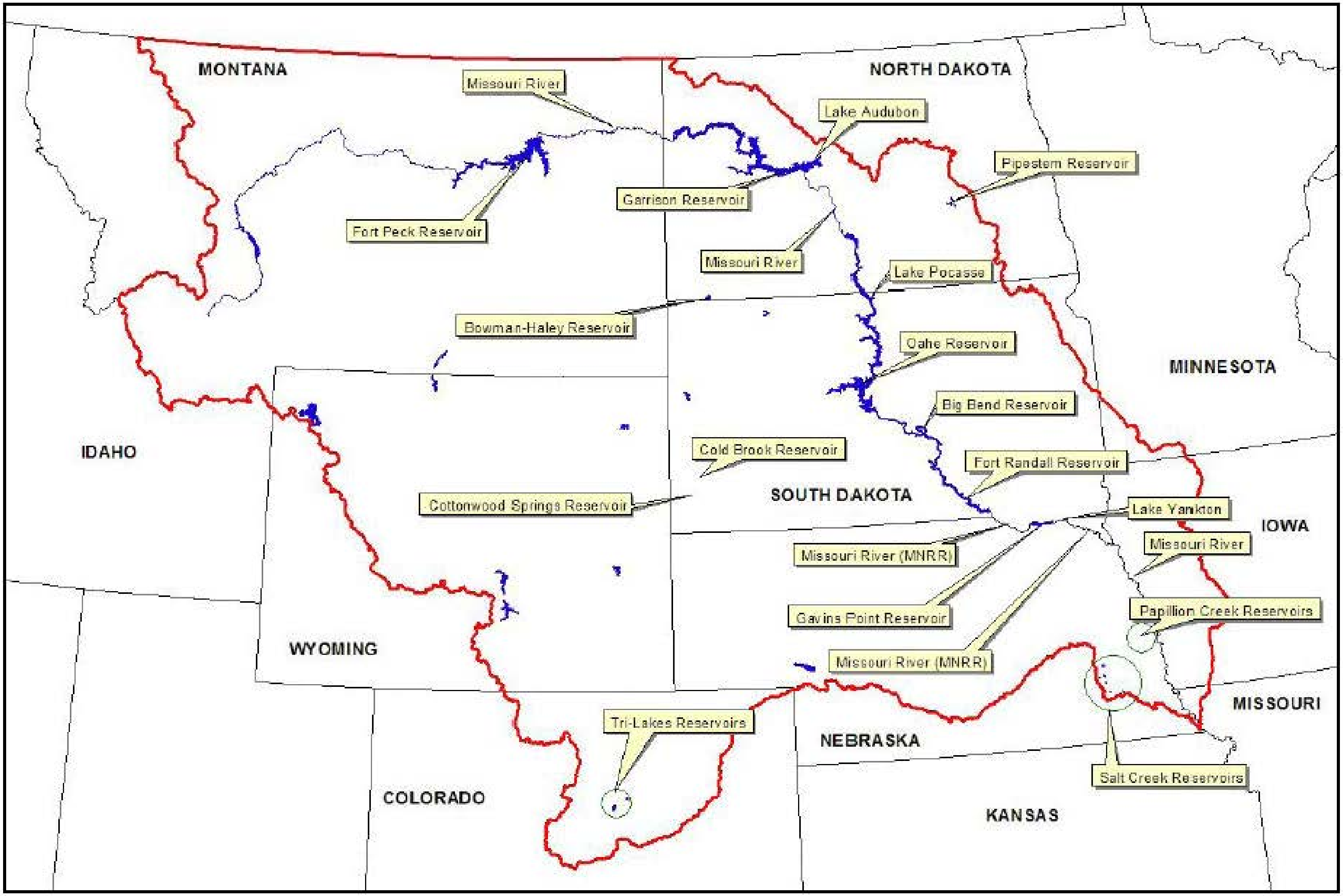

Figure 1.1. Civil works projects in the Omaha District. (Refer to Table 1.1 for project information.)

Table 1.1. Background information for Corps water resource project areas located in the Omaha District.

Project Area	Location	Dam Closure	Lake Size or River Length(1)	Authorized Proposes(2)	Water Quality Designated Beneficial Uses(3)
MAINSTEM RESERVOIRS					
Ft. Peck (Ft. Peck Lake)	Fort Peck, MT	1937	246,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, WAL, DWS, IWS, AWS
Garrison (Lake Sakakawea)	Garrison, ND	1953	380,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(5)	Rec, FW, CAL, DWS, IWS, AWS
Oahe (Lake Oahe)	Pierre, SD	1958	374,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, CAL, DWS, IWS, AWS
Big Bend (Lake Sharpe)	Chamberlain, SD	1963	61,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, CAL, DWS, IWS, AWS
Ft. Randall (Lake Francis Case)	Pickstown, SD	1952	102,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, WAL, DWS, IWS, AWS
Gavins Point (Lewis and Clark Lake)	Yankton, SD	1955	31,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, WAL, DWS, IWS, AWS, Aes
TRIBUTARY RESERVOIRS					
Tri-Lakes Reservoirs (Colorado):					
Bear Creek	Denver, CO	1977	107 A (mp)	FC, Rec, FW	Rec, CAL, DWS, AWS
Chatfield	Denver, CO	1973	1,423 A (mp)	FC, Rec, FW, WS	Rec, CAL, DWS, AWS
Cherry Creek	Denver, CO	1948	844 A (mp)	FC, Rec, FW	Rec, WAL, DWS, AWS
Salt Creek Reservoirs (Nebraska):					
Bluestem (Dam #4)	Lincoln, NE	1962	309 A (cp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Branched Oak (Dam #18)	Lincoln, NE	1967	1,847 A (cp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Conestoga (Dam #12)	Lincoln, NE	1963	217 A (cp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Holmes (Dam #17)	Lincoln, NE	1962	123 A (cp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Olive Creek (Dam #2)	Lincoln, NE	1963	162 A (cp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Pawnee (Dam #14)	Lincoln, NE	1964	739 A (cp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Stagecoach (Dam #9)	Lincoln, NE	1963	195 A (cp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Twin Lakes (East and West) (Dam #13)	Lincoln, NE	1965	236 A (cp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Wagon Train (Dam #8)	Lincoln, NE	1962	277 A (cp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Yankee Hill (Dam #10)	Lincoln, NE	1965	211 A (cp)	FC, Rec, FW	Rec, WAL, AWS, Aes
Papillion Creek Reservoirs (Nebraska):					
Ed Zorinsky (Dam #18)	Omaha, NE	1984	259 A (mp)	FC, Rec, FW, WQ	Rec, WAL, AWS, Aes
Glenn Cunningham (Dam #11)	Omaha, NE	1974	377 A (mp)	FC, Rec, FW, WQ	Rec, WAL, AWS, Aes
Standing Bear (Dam #16)	Omaha, NE	1972	125 A (mp)	FC, Rec, FW, WQ	Rec, WAL, AWS, Aes
Wehrspann (Dam #20)	Omaha, NE	1982	239 A (mp)	FC, Rec, FW, WQ	Rec, WAL, AWS, Aes
North Dakota Reservoirs:					
Bowman-Haley	Bowman, ND	1966	1,732 A (mp)	FC, Rec, FW, WQ, WS	Rec, WAL, FW, AWS
Pipestem	Jamestown, ND	1973	840 A (mp)	FC, Rec, FW, WQ	Rec, WAL, AWS, Aes
South Dakota Reservoirs:					
Cold Brook	Hot Springs, SD	1952	36 A (mp)	FC, Rec, FW, WQ	Rec, FW, CAL, AWS, DWS
Cottonwood Springs	Hot Springs, SD	1969	41 A (mp)	FC, Rec, FW, WQ	Rec, FW, WAL, AWS, DWS
OTHER LAKES					
Lake Audubon (Garrison Project – Snake Creek Dam)	Garrison, ND	1952	18,780 A (mp)	Rec, FW	Rec, FW, WAL, DWS, IWS, AWS
Lake Pocasse (Oahe Project – Spring Creek Dam)	Pollock, SD	1961	1,520 A (mp)	FW	Rec, FW, WAL, AWS
Lake Yankton (Gavins Point Project)	Yankton, SD	1955	250 A	Rec, FW	Rec, WAL, AWS, Aes
MISSOURI RIVER					
Fort Peck Reach	Fort Peck Dam to Garrison Reservoir	---	204 M	----	Rec, FW, CAL, WAL, DWS, IWS, AWS
Garrison Reach	Garrison Dam to Oahe Reservoir	---	87 M	---	Rec, FW, WAL, DWS, IWS, AWS
Oahe Reach	Oahe Dam to Big Bend Reservoir	---	5 M	---	Rec, FW, CAL, DWS, IWS, AWS
Fort Randall Reach	Fort Randall Dam to Gavins Point Reservoir	---	39 M	National Recreational River(6)	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Gavins Point Reach	Gavins Point Dam to Ponca, NE	---	59 M	National Recreational River(6)	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Kesler’s Bend Reach	Ponca, NE to Sioux City, IA	---	17 M	---	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Lower Missouri River Reach	Sioux City, IA to Rulo, NE	---	237 M	BS, Nav	Rec, FW, WAL, DWS, IWS, AWS, Aes

Table. 1.1. (Continued)

(1) A = acres, M = miles, mp = top of multipurpose pool, cp = top of conservation pool.
(2) Purposes authorized under Federal laws for the operation of the Corps projects.
FC = Flood Control, Rec = Recreation, FW = Fish & Wildlife, HP = Hydroelectric Power, WS = Water Supply, WQ = Water Quality, Nav = Navigation, Irrig = Irrigation, BS = Bank Stabilization.
(3) Water quality dependent beneficial uses designated to the water body in State water quality standards pursuant to the Federal Clean Water Act.
Rec = Recreation, FW = Fish and Wildlife, WAL, Warmwater Aquatic Life, CAL = Coldwater Aquatic Life, DWS = Domestic Water Supply, IWS = Industrial Water Supply, AWS = Agricultural Water Supply, Aes = Aesthetics, OSRW = Outstanding State Resource Water.
(4) Section 8 (PL 78-534) Federal irrigation has not been developed at this project; however, water is being withdrawn for private irrigation use.
(5) There is a Section 8 Federal irrigation project authorized at this project, but it is not yet operational; however, water is being withdrawn for private irrigation use.
(6) Designated a Recreational River under the Federal Wild and Scenic Rivers Act.

1.3 WATER QUALITY MONITORING GOALS AND OBJECTIVES

The District has established goals and monitoring objectives for surface water quality monitoring under its WQMP. These monitoring goals and objectives were established to meet the water quality information needs of the WQMP and the water quality management objectives, data collection rules and objectives, data application guidance, and reporting requirements identified in ER 1110-2-8154. Pertinent monitoring goals and objectives that have been established are:

Goal 1: Determine surface water quality conditions at Corps projects.

Monitoring Objectives:

- For all new Corps water resource projects, establish baseline water quality conditions as soon as possible and appropriate.
- Characterize the spatial and temporal distribution of water quality conditions at Corps projects.
- Identify pollutants and their sources that are affecting water quality and the aquatic environment at Corps projects.
- Assess water quality conditions at Corps projects in relation to potential sources, transport, fate, and effects of contaminants.
- Evaluate water/sediment interactions and their effects on overall water quality at Corps projects.
- Identify the presence and concentrations of contaminants in indicator and human-consumed fish species at Corps projects.
- Investigate, as necessary, unique events (e.g., fish kills, hazardous waste spills, operational emergencies, health emergencies, public complaints, etc.) at Corps projects that may have degraded water quality or indicate the aquatic environment has been impacted.

Goal 2: Determine if any surface water concerns exist that are due to the regulation of Corps projects.

Monitoring Objectives:

- Determine if water quality conditions at Corps projects or attributable to the regulation of Corps projects (i.e., downstream conditions resulting from reservoir discharges) meets applicable Federal, Tribal, and State water quality standards.
- Determine if water quality conditions attributed to the regulation of Corps projects are improving, degrading, or staying the same over time.

Goal 3: Quantify any surface water concerns identified at Corps projects.

Monitoring Objectives:

- Apply and calibrate water quality models used to assess water quality concerns at Corps projects.

Goal 4: Provide data to support reservoir regulation elements at Corps projects for effective management and enhancement of surface water quality and the aquatic environment.

- Provide water quality data required for real-time regulation of Corps projects.

- Collect the information needed to design, engineer, and implement measures or modifications at Corps projects to enhance surface water quality and the aquatic environment.

Goal 5: Evaluate the effectiveness of structural or regulation measures implemented at Corps projects to enhance surface water quality and the aquatic environment.

- Evaluate the effectiveness of implemented measures at Corps projects to improve water quality and the aquatic environment.

1.4 DATA COLLECTION APPROACHES

Several data collection approaches have been identified by the District for collecting surface water quality data. Pertinent water quality monitoring approaches are:

- Long-term, fixed station ambient monitoring;
- Intensive surveys;
- Special studies; and
- Investigative monitoring.

Long-term, fixed station ambient monitoring is intended to provide information that will allow the District to determine the status and trends of water quality at Corps projects. This type of sampling consists of systematically collecting samples at the same location over a long period of time (e.g., collecting monthly water samples at the same site for several years).

Intensive surveys are intended to provide more detailed information regarding the water quality conditions at Corps projects. They typically will include more sites sampled over a shorter timeframe than long-term fixed station monitoring. Intensive surveys will provide the detailed water quality information needed to thoroughly understand water quality conditions at a project.

Special studies are conducted to address specific water quality information needs at Corps projects. Among other things, special water quality studies may be undertaken to collect the information needed to "scope-out" a specific water quality problem, calibrate water quality models, design and engineer modifications at projects, or evaluate the effectiveness of specific implemented water quality enhancement measures.

Investigative monitoring is typically initiated in response to an immediate need for water quality information. This may be in response to an operational situation at a Corps project, the occurrence of a significant pollution event, public complaint, or a report of a fish kill. Any District response to a pollution event or fish kill would need to be coordinated with the appropriate Tribal, State, and Local agencies. The type of sampling that is done for investigative purposes is highly specific to the situation under investigation.

1.5 GENERAL WATER QUALITY CONCERNS IN THE OMAHA DISTRICT

1.5.1 LAKE EUTROPHICATION AND HYPOLIMNETIC DISSOLVED OXYGEN DEPLETION

Reservoirs are commonly classified or grouped by trophic or nutrient status. The natural progression of reservoirs through time is from an oligotrophic (i.e., low nutrient/low productivity) through a mesotrophic (i.e., intermediate nutrient/intermediate productivity) to a eutrophic (i.e., high nutrient/high productivity) condition. The tendency toward the eutrophic or nutrient-rich status is common to all impounded waters. The eutrophication, or enrichment process, can be accelerated by nutrient additions to the lake resulting from cultural activities.

As deeper, temperate lakes warm in the spring and summer they typically become thermally stratified, due to the density differences of the water, into three vertical zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion. The epilimnion is the upper zone of less dense, warmer water in the lake that remains relatively mixed due to wind action and convection. The metalimnion is the middle zone that represents the transition from warm surface water to cooler bottom water. The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent.

A significant water quality concern that can occur in reservoirs that thermally stratify in the summer is the depletion of dissolved oxygen levels in the hypolimnion. The depletion of dissolved oxygen is attributed to the differing density of water with temperature, the utilization of in-lake dissolved oxygen in the decomposition of organic matter, and the oxidation of reduced inorganic substances. When density differences become significant, the deeper colder water is isolated from the surface and re-oxygenation from the atmosphere. In eutrophic lakes, the decomposition of the abundant organic matter can significantly reduce dissolved oxygen in the quiescent hypolimnetic zone. Anoxic conditions in the hypolimnion can result in the release of sediment-bound substances (e.g., phosphorus, metals, sulfides, etc.) as the reduced conditions intensify and result in the production of toxic and caustic substances (e.g., hydrogen sulfide, etc.). Most fish and other intolerant aquatic life cannot inhabit water with less than 4 to 5 mg/l dissolved oxygen for extended periods. These conditions can impact aquatic life in the lake and also in waters downstream of the reservoir if its releases are from a bottom outlet.

1.5.2 SEDIMENTATION

Sedimentation is a process that reduces the usefulness of reservoirs. In the design and construction of reservoirs, the Corps will commonly allow for additional volume to accommodate sedimentation. The incoming sediment can seriously affect the reservoir ecology, fisheries, and benthic aquatic life. The reservoir can suffer ecological damage before a volume function such as flood control is impacted. The influx of sediment eliminates fish habitat, adds nutrients, destroys aesthetics, and decreases biodiversity. Working closely with the project sponsors in an effort to manage sediment input could ultimately prolong reservoir life. Wetlands or sediment traps could be constructed at the headwaters of a reservoir, either upstream of the reservoir or by taking a portion of the reservoir's upper end.

1.5.3 SHORELINE EROSION

Shoreline erosion is a major problem occurring on nearly all reservoirs located in areas of erodible soils such as the Midwest. Over 6,000 miles of reservoir shoreline exist at Corps projects in the District, and it is estimated that over 70 percent of this shoreline is eroding. Some locations have been protected, such as recreational and archaeological sites, but most of the shoreline continues to erode. Continued loss of the shoreline habitat (littoral zone) results in the loss of fishery habitat as well as loss of habitat for other biota such as aquatic vegetation and benthic invertebrates. Past shoreline erosion control efforts should be evaluated for effectiveness so that successful control measures can be identified for future application.

1.5.4 BIOACCUMULATION OF CONTAMINANTS IN AQUATIC ORGANISMS

Bioaccumulation is the accumulation of contaminants in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water or sediment. Bioavailable, for chemicals, is the state of being potentially available for biological uptake by an aquatic organism when that organism is processing or encountering a given environmental medium (e.g., the chemicals that can be extracted by the gills from the water as it passes through the respiratory cavity or the chemicals that are absorbed by internal membranes as the organism moves through or ingests

sediment). In the aquatic environment, a chemical can exist in three different basic forms that affect availability to organisms: 1) dissolved, 2) sorbed to biotic or abiotic components and suspended in the water column or deposited on the bottom, and 3) incorporated (accumulated) into organisms. Bioconcentration is a process by which there is a net accumulation of a chemical directly from water into aquatic organisms resulting from simultaneous uptake (e.g., by gill or epithelial tissue) and elimination. Biomagnification is the result of the process of bioconcentration and bioaccumulation by which tissue concentrations of bioaccumulated chemicals increase as the chemical passes up through two or more trophic levels. The term implies an efficient transfer of a chemical from food to consumer so that residual concentrations increase systematically from one trophic level to the next.

Bioaccumulation of contaminants can have a direct effect on aquatic organisms. These effects can be chronic (reduced growth, fecundity, etc.) and acute (lethality). The bioaccumulation of contaminants can also be a concern to human health when the contaminated tissue of aquatic organisms is consumed by humans.

1.5.5 OCCURRENCE OF PESTICIDES

Pesticides are widely applied to lands throughout the District. Pesticides detected at Corps projects in the District over the past 5 years include: acetochlor, alachlor, atrazine, isopropalin, metolachlor, metribuzin, prometon, propazine, and trifluralin. Many of these pesticides do not have State or Federal numeric water quality criteria established.

1.5.6 URBANIZATION

Urbanization around many District reservoirs is occurring at a rapid pace. Reservoirs with urbanizing watersheds include Cherry Creek, Chatfield, and Bear Creek in the Denver, Colorado area; Holmes in the Lincoln, Nebraska area; and Ed Zorinsky, Glen Cunningham, Standing Bear, and Wehrspann in the Omaha, Nebraska area. Urbanization, to a much lesser degree, is occurring at other Corps projects in the District.

Construction methods used to develop urban areas disturb the land and allow sediment-laden runoff to impact nearby streams and lakes. Best management practices (BMPs) to minimize construction associated sedimentation damages are used ineffectively in many cases. BMPs to control the impact of construction practices include; sediment retention basins, phased “grading”, and runoff control (e.g. hay bales, silt fences, vegetative ground cover, terracing, etc). Efforts need to be made to prevent sedimentation from off-project construction activities from causing impacts to Corps projects. This could be accomplished by the appropriate State, County, or City agencies working with developers.

Post-construction problems are commonly associated with storm drainage and urban pollution. The conversion of grasslands or forests to roads, rooftops, sidewalks, and other water impervious surfaces make stream flows more variable and increases the frequency of high flow events. In addition, pollutants associated with urban drainage can cause impacts to downstream water bodies. Storm sewer exits can be allowed on project lands provided detention in the form of ponds, swales, or wetlands exist on private property. A developer may be asked to construct a series of wetlands to slow downhill flows and provide time for bacterial die-off, chemical degradation, reduced flow rates, and sediment settling.

1.6 PRIORITIZATION OF DISTRICT-WIDE WATER QUALITY MANAGEMENT ISSUES

The District has identified seven priority issues for water quality management. These priority issues and their relative ranking are listed in Table 1.2.

Table 1.1. Priority water quality management issues within the Omaha District.

Ranking*	Water Quality Management Issue
1	Determine how regulation of the Missouri River Mainstem System (Mainstem System) dams affects water quality in the impounded reservoir and downstream river. Utilize the CE-QUAL-W2 hydrodynamic and water quality model to facilitate this effort.
2	Evaluate how eutrophication is progressing in the Mainstem System reservoirs, especially regarding the expansion of anoxic conditions in the hypolimnion during summer stratification.
3	Determine how flow regime, especially the release of water from Mainstem System projects, affects water quality in the Missouri River.
4	Provide water quality information to support Corps reservoir regulation elements for effective water quality and aquatic habitat management.
5	Provide water quality information and technical support to the States in the development of their Section 303(d) lists and development and implementation of TMDLs at District projects.
6	Identify existing and potential water quality problems at District projects and develop and implement appropriate solutions.
7	Evaluate water quality conditions and trends at District projects.

* 1 = Highest priority, 7 = Lowest Priority

1.7 PROJECT-SPECIFIC WATER QUALITY MANAGEMENT ISSUES AND CONCERNS IN THE OMAHA DISTRICT

1.7.1 SECTION 303(D) LISTING OF IMPAIRED WATERS

Under Section 303(d) of the Federal Clean Water Act (CWA), Tribes and States, with the delegated authority from the U.S. Environmental Protection Agency (EPA), are required to prepare a biennial list of impaired waters [i.e., Section 303(d) list]. Impaired waters refer to those water bodies where it has been determined that technology-based effluent limitations required by Section 301 of the CWA are not stringent enough to attain and maintain applicable water quality standards. Tribes and States, as appropriate, are required to establish and implement Total Maximum Daily Loads (TMDLs) for water bodies on their Section 303(d) lists.

1.7.2 FISH CONSUMPTION ADVISORIES

Fish are capable of accumulating many toxic substances in excess of 1,000 times the concentrations found in surface waters. The public has expressed concerns on whether fish caught from Corps project waters are safe to consume. It is important that answers to public health concerns be based on substantiated knowledge of toxicants in fish fillets and the public health risks associated with measured toxicant concentrations. This type of information can be used by States when considering the issuance of fish consumption advisories. Fish consumption advisories have been issued for fish caught from certain District project waters. Mercury is the most prevalent contaminant leading to the issuance of fish consumption advisories in the Omaha District.

1.7.3 SUMMARY OF PROJECT-SPECIFIC WATER QUALITY MANAGEMENT ISSUES AND CONCERNS

Table 1.3 summarizes Section 303(d) listings, fish consumption advisories, and other miscellaneous water quality concerns applicable to Corps projects in the Omaha District.

Table 1.2. Summary of project-specific water quality management issues and concerns.

Project Area	TMDL Considerations*				Fish Consumption Advisories		Other Water Quality Management Issues
	On 303(d) List	Impaired Uses	Pollutant/Stressor	TMDL Completed	Advisory in Effect	Identified Contamination	
Missouri River Mainstem System Projects:							
Missouri River (Bullwhacker Creek to Fort Peck Reservoir)	Yes	Aquatic Life Drinking Water Supply Warmwater Fishery	Arsenic, Copper Metals Other Habitat Alterations Riparian Degradation	No	No		Pallid sturgeon recovery priority area
Fort Peck Reservoir	Yes	Drinking Water Supply Recreation	Lead, Mercury Metals Noxious Aquatic Plants	No	Yes	Mercury	
Missouri River – Fort Peck Dam to Lake Sakakawea	Yes	Aquatic Life Coldwater Fishery – Trout Warmwater Fishery	Flow Alteration Other Habitat Alterations Riparian Degradation Thermal Modifications	No	No		Pallid sturgeon recovery priority area
Garrison Reservoir	Yes	Fish and Other Aquatic Biota Fish Consumption	Low Dissolved Oxygen Water Temperature Methyl-Mercury	No	Yes	Mercury	Hypolimnetic dissolved oxygen
Missouri River – Garrison Dam tailwaters	No				Yes	Mercury	Low dissolved oxygen in Garrison Dam tailwaters (associated with late summer hypolimnetic reservoir withdrawals)
Lake Pocasse (Oahe Reservoir)	Yes	Warmwater Fishery	Eutrophication	No	No		
Big Bend Reservoir	No			Yes	No		TMDL developed for sediment. A nonpoint source management project is being implemented in the Bad River watershed.
Missouri River – Fort Randall Dam to Gavins Point Reservoir	No				No		National recreational river Pallid sturgeon recovery priority area
Gavins Point Reservoir	No				No		Sedimentation Emergent aquatic vegetation
Missouri River downstream from Gavins Point Dam	Yes	Recreation Aquatic Life	Pathogens Dieldrin, PCBs	No	Yes	Dieldrin PCBs	National recreational river Pallid sturgeon recovery priority area Summer ambient water temperature (NPDES limitations regarding cooling water discharges)
Missouri River (Council Bluffs, IA)	Yes	Drinking Water Supply	Arsenic	No	-----		
Colorado Tributary Projects:							
Bear Creek Reservoir	Yes	Aquatic Life	Dissolved Oxygen**	No	No		Site specific water quality criteria (phosphorus and chlorophyll)
Chatfield Reservoir	No				No		Site specific water quality criteria (phosphorus and chlorophyll)
Cherry Creek Reservoir	Yes	Aquatic Life Recreation	Chlorophyll a Dissolved Oxygen **	No	No		Site specific water quality criteria (phosphorus and chlorophyll)
So. Platte River – North Fork South Platte River to Chatfield Reservoir.	Yes	Aquatic Life	Sediment**	-----	No		

* Information taken from published State Total Maximum Daily Load (TMDL) 303(d) reports and listings as of January 1, 2006.

** Identified on Colorado's Monitoring and Evaluation List. Water quality problem suspected, but uncertainty exists based on available data.

Table 1.3. Summary of project-specific water quality management issues and concerns (Continued).

Project Area	TMDL Considerations*				Fish Consumption Advisories		Other Potential Water Quality Concerns
	On 303(d) List	Impaired Uses	Pollutant/Stressor	TMDL Completed	Advisory in Effect	Identified Contamination	
Nebraska Tributary Projects:							
Bluestem Reservoir	Yes	Recreation Aquatic Life Aesthetics	Bacteria Nutrients Sediment	No	No		Algal blooms
Conestoga Reservoir	Yes	Aquatic Life Aesthetics	Nutrients Sediment	No	No		Algal blooms Cyanobacteria toxins
East Twin Reservoir	Yes	Aquatic Life Aesthetics	Sediment	No	No		Algal blooms
Ed Zorinsky Reservoir	Yes	Aquatic Life	Mercury	Yes	Yes	Mercury	TMDLs for dissolved oxygen, nutrients, and sediment approved (2002)
Glenn Cunningham Reservoir	Yes	Aquatic Life	Sediment	No	No		Algal blooms
Holmes Reservoir	No	-----	-----	Yes	No		TMDLs for nutrients and sediment approved (2003)
Olive Creek Reservoir	Yes	Aquatic Life Aesthetics	Nutrients pH	No	No		Algal blooms
Pawnee Reservoir	No	-----	-----	Yes	No		TMDL for sediment approved (2001) Algal blooms Cyanobacteria toxins
Stagecoach Reservoir	Yes	Aquatic Life Aesthetics	Nutrients	No	No		Algal blooms
Standing Bear Reservoir	Yes	Aquatic Life	Mercury	Yes	Yes	Mercury	TMDLs for sediment, dissolved oxygen, and nutrients approved (2003)
Wagon Train Reservoir	No	-----	-----	Yes	No		TMDLs for sediment, dissolved oxygen, and nutrients approved (2002)
Wehrspann Reservoir	Yes	Aquatic Life	Mercury	No	Yes	Mercury	Algal blooms
West Twin Reservoir	Yes	Aquatic Life Aesthetics	Nutrients Sediment	No	No		Algal blooms
Yankee Hill Reservoir	No	-----	-----	Yes	No		TMDLs for nutrients and sediment approved (2003)
North Dakota Tributary Projects:							
Bowman-Haley Reservoir	No				Yes	Mercury	Algal blooms
Pipestem Reservoir	Yes	Recreation	Nutrients/Eutrophication	No	Yes	Mercury	Algal blooms
Pipestem Creek (Pipestem Dam to confluence with Little Pipestem Creek)	Yes	Recreation	Bacteria	No	Yes	Mercury	

* Information taken from published State Total Maximum Daily Load (TMDL) Section 303(d) reports and listings.

2 LIMNOLOGICAL PROCESSES IN RESERVOIRS

Many of the Corps civil works projects in the District involve the operation and maintenance of a reservoir or the regulation of flows discharged from reservoirs. Much of the water quality monitoring conducted by the District is done to determine existing water quality conditions and identify water quality management concerns at these reservoirs. A basic understanding of the limnological processes that occur in reservoirs is needed to interpret the water quality information provided in this report. The following discussion provides a basic overview of limnological processes that occur in reservoirs.

2.1 VERTICAL AND LONGITUDINAL WATER QUALITY GRADIENTS

The annual temperature distribution represents one of the most important limnological processes occurring within a reservoir. Thermal variation in a reservoir results in temperature-induced density stratification, and an understanding of the thermal regime is essential to water quality assessment. Deep, temperate-zone lakes typically completely mix from the surface to the bottom twice a year (i.e., dimictic). Temperate-zone dimictic lakes exhibit thermally-induced density stratification in the summer and winter months that is separated by periods of "turnover" in the spring and fall. This stratification typically occurs through the interaction of wind and solar insolation at the lake surface and creates density gradients that can influence lake water quality. During the summer, solar insolation has its highest intensity and the reservoir becomes stratified into three zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion.

Epilimnion: The epilimnion is the upper zone that consists of the less dense, warmer water in the reservoir. It is fairly turbulent since its thickness is determined by the turbulent kinetic energy inputs (e.g., wind, convection, etc.), and a relatively uniform temperature distribution throughout this zone is maintained.

Metalimnion: The metalimnion is the middle zone that represents the transition from warm surface water to colder bottom water. There is a distinct temperature gradient through the metalimnion. The metalimnion contains the thermocline that is the plane or surface of maximum temperature rate change.

Hypolimnion: The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent. Bottom withdrawal or fluctuating water levels in reservoirs, however, may significantly increase hypolimnetic mixing.

Long, dendritic reservoirs, with tributary inflows located a considerable distance from the outflow and unidirectional flow from headwater to dam develop gradients in space and time (USACE, 1987). Although these gradients are continuous from headwater to dam, three characteristic zones result: a riverine zone, a zone of transition, and a lacustrine zone (USACE, 1987).

Riverine Zone: The riverine zone is relatively narrow, well mixed, and although water current velocities are decreasing, advective forces are still sufficient to transport significant quantities of suspended particles, such as silts, clays, and organic particulate. Light penetration in this zone is minimal and may be the limiting factor that controls primary productivity in the water column. The decomposition of tributary organic loadings often creates a significant oxygen demand, but an aerobic environment is maintained because the riverine zone is generally shallow and well mixed. Longitudinal dispersion may be an important process in this zone.

Zone of Transition: Significant sedimentation occurs through the transition zone, with a subsequent increase in light penetration. Light penetration may increase gradually or abruptly, depending on the flow regime. At some point within the mixed layer of the zone of transition, a compensation point between the production and decomposition of organic matter should be reached. Beyond this point, production of organic matter within the reservoir mixed layer should begin to dominate.

Lacustrine Zone: The lacustrine zone is characteristic of a lake system. Sedimentation of inorganic particulate is low. Light penetration is sufficient to promote primary production, with nutrient levels the limiting factor and production of organic matter exceeds decomposition within the mixed layer. Entrainment of metalimnetic and hypolimnetic water, particulate, and nutrients may occur through internal waves or wind mixing during the passage of large weather fronts. Hypolimnetic mixing may be more extensive in reservoirs than “natural” lakes because of bottom withdrawal. In addition, an intake structure may simultaneously remove water from the hypolimnion and metalimnion.

When tributary inflow enters a reservoir, it displaces the reservoir water. If there is no density difference between the inflow and reservoir waters, the inflow moves as a density current in the form of overflows, interflows, or underflows. Internal mixing is the term used to describe mixing within a reservoir from such factors as wind, Langmuir circulation, convection, Kelvin-Helmholtz instabilities, and outflow (USACE, 1987).

2.2 CHEMICAL CHARACTERISTICS OF RESERVOIR PROCESSES

2.2.1 CONSTITUENTS

Some of the most important chemical constituents in reservoir waters that affect water quality are needed by aquatic organisms for survival. These include oxygen, carbon, nitrogen, and phosphorus. Other important constituents are silica, manganese, iron, and sulfur.

Dissolved oxygen: Oxygen is a fundamental chemical constituent of water bodies that is essential to the survival of aquatic organisms and is one of the most important indicators of reservoir water quality conditions. The distribution of dissolved oxygen (DO) in reservoirs is a result of dynamic transfer processes from the atmospheric and photosynthetic sources to consumptive uses by the aquatic biota. The resulting distribution of DO in the reservoir water strongly affects the solubility of many inorganic chemical constituents. Often, water quality control or management approaches are formulated to maintain an aerobic, or oxic (i.e., oxygen-containing), environment. Oxygen is produced by aquatic plants (phytoplankton and macrophytes) and is consumed by aquatic plants, other biological organisms, and chemical oxidations. In reservoirs, the DO demand may be divided into two separate but highly interactive fractions: sediment oxygen demand (SOD) and water column oxygen demand.

Sediment oxygen demand: The SOD is typically highest in the upstream area of the reservoir just below the headwaters. This is an area of transition from riverine to lake characteristics. It is relatively shallow but stratifies. The loading and sedimentation of organic matter is high in this transition area and, during stratification, the hypolimnetic DO to satisfy this demand can be depleted. If anoxic conditions develop, they generally do so in this area of the reservoir and progressively move toward the dam during the stratification period. The SOD is relatively independent of DO when DO concentrations in the water column are greater than 3 to 4 mg/l but becomes limited by the rate of oxygen supply to the sediments.

Water column oxygen demand: A characteristic of many reservoirs is a metalimnetic minimum in DO concentrations, or negative heterograde oxygen curve (Figure 2.1). Density interflows not only transport oxygen-demanding material into the metalimnion, but can also entrain reduced chemicals from the upstream anoxic area and create additional oxygen demand. Organic matter and organisms from the

mixed layer settle at slower rates in the metalimnion because of increased viscosity due to lower temperatures. Since this labile organic matter remains in the metalimnion for a longer time period, decomposition occurs over a longer time, exerting a higher oxygen demand. Metalimnetic oxygen depletion is an important process in deep reservoirs. A hypolimnetic oxygen demand generally starts at the sediment/water interface unless underflows contribute organic matter that exerts a significant oxygen demand. In addition to metalimnetic DO depletion, hypolimnetic DO depletion also is important in shallow, stratified reservoirs since there is a smaller hypolimnetic volume of oxygen to satisfy oxygen demands than in deeper reservoirs.

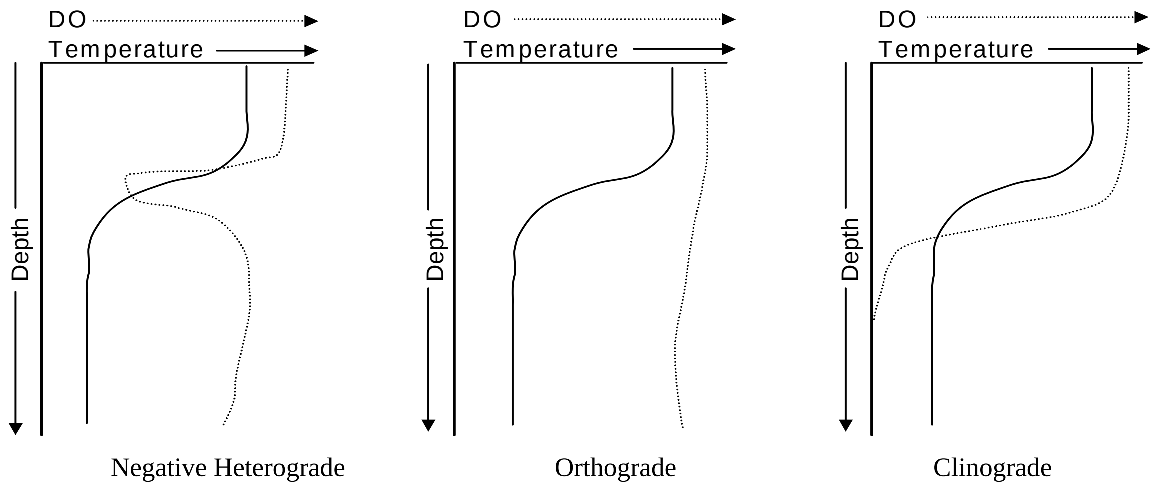

Figure 2.1. Vertical oxygen concentrations possible in thermally stratified lakes.

<u>*Dissolved oxygen distribution*</u>: Two basic types of vertical DO distribution may occur in the water column: an orthograde and clinograde DO distribution (Figure 2.1). In the orthograde distribution, DO concentration is a function primarily of temperature, since DO consumption is limited. The clinograde DO profile is representative of more productive, nutrient-rich reservoirs where the hypolimnetic DO concentration progressively decreases during stratification and can occur during both summer and winter stratification periods.

<u>Inorganic carbon</u>: Inorganic carbon represents the basic building block for the production of organic matter by plants. Inorganic carbon can also regulate the pH and buffering capacity or alkalinity of aquatic systems. Inorganic carbon exists in a dynamic equilibrium in three major forms: carbon dioxide (CO_2), bicarbonate ions (HCO_3), and carbonate ions (CO_3). Carbon dioxide is readily soluble in water and some CO_2 remains in a gaseous form, but the majority of the CO_2 forms carbonic acid that dissociates rapidly into HCO_3 and CO_3 ions. This dissociation results in a weakly alkaline system (i.e., pH $\approx$ 7.1 or 7.2). There is an inverse relationship between pH and CO_2. The pH increases when aquatic plants (phytoplankton or macrophytes) remove CO_2 from the water to form organic matter through photosynthesis during the day. During the night when aquatic plants respire and release CO_2, the pH decreases. The extent of this pH change provides an indication of the buffering capacity of the system. Weakly buffered systems with low alkalinities (i.e., <500 microequivalents per liter) experience larger shifts in pH than well-buffered systems (i.e., >1,000 microequivalents per liter).

Nitrogen: Nitrogen is important in the formulation of plant and animal protein. Nitrogen, similar to carbon, also has a gaseous form. Many species of cyanobacteria can use or fix elemental or gaseous N_2 as a nitrogen source. The most common forms of nitrogen in aquatic systems are ammonia (NH_3-N), nitrite (NO_2-N), and nitrate (NO_3-N). All three forms are transported in water in a dissolved phase. Ammonia results primarily from the decomposition of organic matter. Nitrite is primarily an intermediate compound in the oxidation or nitrification of ammonia to nitrate, while nitrate is the stable oxidation state of nitrogen and represents the other primary inorganic nitrogen form besides NH_3 used by aquatic plants.

Phosphorus: Phosphorus is used by both plants and animals to form enzymes and vitamins and to store energy in organic matter. Phosphorus has received considerable attention as the nutrient controlling algal production and densities and associated water quality problems. The reasons for this emphasis are: phosphorus tends to limit plant growth more than the other major nutrients; phosphorus does not have a gaseous phase and ultimately originates from the weathering of rocks; removal of phosphorus from point sources can reduce the growth of aquatic plants; and the technology for removing phosphorus is more advanced and less expensive than nitrogen removal. Phosphorus is generally expressed in terms of the chemical procedures used for measurement: total phosphorus, particulate phosphorus, dissolved or filterable phosphorus, and soluble reactive phosphorus. Phosphorus is a very reactive element; it reacts with many cations such as iron and calcium and is readily sorbed on particulate matter such as clays, carbonates, and inorganic colloids. Since phosphorus exists in a particulate phase, sedimentation represents a continuous loss from the water column to the sediment. Sediment phosphorus, then, may exhibit longitudinal gradients in reservoirs similar to sediment silt/clay gradients. Phosphorus contributions from sediment under anoxic conditions and macrophyte decomposition are considered internal phosphorus sources or loads, and are in a chemical form readily available for plankton uptake and use. Internal phosphorus loading can represent a major portion of the total phosphorus budget.

Silica: Silica is an essential component of diatom algal frustules or cell walls. Silica uptake by diatoms can markedly reduce silica concentrations in the epilimnion and initiate a seasonal succession of diatom species. When silica concentrations decrease below 0.5 mg/l, diatoms generally are no longer competitive with other phytoplankton species.

Other nutrients: Iron, manganese, and sulfur concentrations generally are adequate to satisfy plant nutrient requirements. Oxidized iron (III) and manganese (IV) are quite insoluble in water and occur in low concentrations under aerobic conditions. Under aerobic conditions, sulfur usually is present as sulfate.

2.2.2 ANAEROBIC (ANOXIC) CONDITIONS

When dissolved oxygen concentrations in the hypolimnion are reduced to approximately 2 to 3 mg/l, the oxygen regime at the sediment/water interface is generally considered anoxic, and anaerobic processes begin to occur in the sediment interstitial water. Nitrate reduction to ammonium and/or N_2O or N_2 (denitrification) is considered to be the first phase of the anaerobic process and places the system in a slightly reduced electrochemical state. Ammonium-nitrogen begins to accumulate in the hypolimnetic water. The presence of nitrate prevents the production of additional reduced forms such as manganese (II), iron (II), or sulfide species. Denitrification probably serves as the main mechanism for removing nitrate from the hypolimnion. Following the reduction or denitrification of nitrate, manganese species are reduced from insoluble forms (i.e., Mn (IV)) to soluble manganous forms (i.e.,Mn (II)), which diffuse into the overlying water column. Nitrate reduction is an important step in anaerobic processes since the presence of nitrate in the water column will inhibit manganese reduction. As the electrochemical potential of the system becomes further reduced, iron is reduced from the insoluble ferric (III) form to the soluble ferrous (II) form, and begins to diffuse into the overlying water column. Phosphorus, in many instances, is also transported in a complexed form with insoluble ferric (III) species so the reduction and

solubilization of iron also result in the release and solubilization of phosphorus into the water column. The sediments may serve as a major phosphorus source during anoxic periods and a phosphorus sink during aerobic periods. During this period of anaerobiosis, microorganisms also are decomposing organic matter into lower molecular weight acids and alcohols such as acetic, fulvic, humic, and citric acids and methanol. These compounds may also serve as trihalomethane precursors (low-molecular weight organic compounds in water; i.e., methane, formate acetate), which, when subject to chlorination during water treatment, form trihalomethanes, or THMs (carcinogens). As the system becomes further reduced, sulfate is reduced to sulfide, which begins to appear in the water column. Sulfide will readily combine with soluble reduced iron (II), however, to form insoluble ferrous sulfide, which precipitates out of solution. If the sulfate is reduced to sulfide and the electrochemical potential is strongly reducing, methane formation from the reduced organic acids and alcohols may occur. Consequently, water samples from anoxic depths will exhibit these chemical characteristics.

Anaerobic processes are generally initiated in the upstream portion of the hypolimnion where organic loading from the inflow is relatively high and the volume of the hypolimnion is minimal, so oxygen depletion occurs rapidly. Anaerobic conditions are generally initiated at the sediment/water interface and gradually diffuse into the overlying water column and downstream toward the dam. Anoxic conditions may also develop in a deep pocket near the dam due to decomposition of autochthonous organic matter settling to the bottom. This anoxic pocket, in addition to expanding vertically into the water column, may also move upstream and eventually meet the anoxic zone moving downstream.

Anoxic conditions are generally associated with the hypolimnion, but anoxic conditions may occur in the metalimnion. The metalimnion may become anoxic due to microbial respiration and decomposition of plankton settling into the metalimnion, microbial metabolism of organic matter entering as an interflow, or through entrainment of anoxic hypolimnetic water from the upper portion of the reservoir.

2.3 BIOLOGICAL CHARACTERISTICS AND PROCESSES

2.3.1 MICROBIOLOGICAL

The microorganisms associated with reservoirs may be categorized as pathogenic or nonpathogenic. Pathogenic microorganisms are of a concern from a human health standpoint and may limit recreational and other uses of reservoirs. Nonpathogenic microorganisms are important in that they often serve as decomposers of organic matter and are a major source of carbon and energy for a reservoir. Microorganisms generally inhabit all zones of the reservoir as well as all layers. Seasonally high concentrations of bacteria will occur during the warmer months, but they can be diluted by high discharges. Anaerobic conditions enhance growth of certain bacteria while aeration facilitates the use of bacterial food sources. Microorganisms, bacteria in particular, are responsible for mobilization of contaminants from sediments.

2.3.2 PHOTOSYNTHESIS

Oxygen is a by-product of aquatic plant photosynthesis, which represents a major source of oxygen for reservoirs during the growing season. Oxygen solubility is less during the period of higher water temperatures, and diffusion may also be less if wind speeds are lower during the summer than the spring or fall. Biological activity and oxygen demand typically are high during thermal stratification, so photosynthesis may represent a major source of oxygen during this period. Oxygen supersaturation in the euphotic zone can occur during periods of high photosynthesis.

2.3.3 PLANKTON

Phytoplankton influence dissolved oxygen and suspended solids concentrations, transparency, taste and odor, aesthetics, and other factors that affect reservoir uses and water quality objectives. Phytoplankton are a primary source of organic matter production and form the base of the autochthonous food web in many reservoirs since fluctuating water levels may limit macrophyte and periphyton production. Phytoplankton can be generally grouped as diatoms, green algae, cyanobacteria, or cryptomonad algae. Chlorophyll *a* represents a common variable used to estimate phytoplankton biomass.

Seasonal succession of phytoplankton species is a natural occurrence in reservoirs. The spring assemblage is usually dominated by diatoms and cryptomonads. Silica depletion in the photic zone and increased settling as viscosity decreases because of increased temperatures usually result in green algae succeeding the diatoms. Decreases in nitrogen or a decreased competitive advantage for carbon at higher pH may result in cyanobacteria succeeding the green algae during summer and fall. Diatoms generally return in the fall, but cyanobacteria, greens, or diatoms may cause algae blooms following fall turnover when hypolimnetic nutrients are mixed throughout the water column. The general pattern of seasonal succession of phytoplankton is fairly constant from year to year. However, hydrologic variability, such as increased mixing and delay in the onset of stratification during cool, wet spring periods, can maintain diatoms longer in the spring and shift or modify the successional pattern of algae in reservoirs.

Phytoplankton grazers can reduce the abundance of algae and alter their successional patterns. Some phytoplankton species are consumed and assimilated more readily and are preferentially selected by consumers. Single-celled diatom and green algae species are readily consumed by zooplankton, while filamentous cyanobacteria are avoided by zooplankters. Altering the fish population can result in a change in the zooplankton population that can affect the phytoplankton population.

2.3.4 ORGANIC CARBON AND DETRITUS

Total organic carbon (TOC) is composed of dissolved organic carbon (DOC) and particulate organic carbon (POC). Detritus represents that portion of the POC that is nonliving. Nearly all the TOC of natural waters consists of DOC and detritus, or dead POC. The processes of decomposition and consumption of TOC are important in reservoirs and can have a significant affect on water quality.

DOC and POC are decomposed by microbial organisms. This decomposition exerts an oxygen demand that can remove dissolved oxygen from the water column. During stratification, the metalimnion and hypolimnion become relatively isolated from sources of dissolved oxygen, and depletion can occur through organic decomposition. There are two major sources of this organic matter: allochthonous (i.e., produced outside the reservoir and transported in) and autochthonous (i.e., produced within the reservoir). Allochthonous organic carbon in small streams may be relatively refractory since it consists of decaying terrestrial vegetation that has washed or fallen into the stream. Larger rivers, however, may contribute substantial quantities of riverine algae or periphyton that decompose rapidly and can exert a significant oxygen demand. Autochthonous sources include dead plankton settling from the mixed layers and macrophyte fragments and periphyton transported from the littoral zone. These sources are also rapidly decomposed.

POC and DOC absorbed onto sediment particles may serve as a major food source for aquatic organisms. The majority of the phytoplankton production enters the detritus food web with a minority being grazed by primary consumers (USACE, 1987). While autochthonous production is important in reservoirs, typically as much as three times the autochthonous production may be contributed by allochthonous material (USACE, 1987).

2.4 BOTTOM WITHDRAWAL RESERVOIRS

Bottom withdrawal structures are located near the deepest part of a reservoir. Bottom withdrawal removes hypolimnetic water and nutrients and may promote movement of interflows or underflow into the hypolimnion. They release cold water from the deep portion of the reservoir; however, this water may be anoxic during periods of stratification. Bottom outlets can cause density interflows or underflows (e.g., flow laden with sediment or dissolved solids) through the reservoir and generally provide little or no direct control over release water quality.

3 OMAHA DISTRICT WATER QUALITY MONITORING

3.1 MISSOURI RIVER MAINSTEM SYSTEM

3.1.1 MISSOURI RIVER MAINSTEM SYSTEM RESERVOIRS

3.1.1.1 Long-Term Fixed Station Ambient Monitoring

Long-term, fixed station ambient monitoring has occurred at the six Missouri River Mainstem System (Mainstem System) reservoirs (i.e., Fort Peck Lake, Lake Sakakawea, Lake Oahe, Lake Sharpe, Lake Francis Case, and Lewis and Clark Lake) for the past 30 years. Recent ambient monitoring conducted by the District at the Mainstem System reservoirs included monthly (i.e., May through September) water quality monitoring at a near-dam, deepwater site. Water quality monitoring included field measurements and collection of water samples for analytical analysis. Field measurements included water transparency (i.e., Secchi depth) and measuring temperature, dissolved oxygen, pH, conductivity, oxidation-reduction potential (ORP), chlorophyll a, and turbidity at 1-meter increments from the reservoir surface to the bottom. Near-surface and near-bottom grab samples were collected and delivered to the laboratory where they were analyzed for alkalinity, nitrate/nitrite, total ammonia, Kjeldahl nitrogen, total phosphorus, ortho-phosphorus, suspended solids, total organic carbon, pesticides, and various metals. A near-surface grab sample was also collected in the epilimnion for analysis of chlorophyll *a* and phytoplankton taxa occurrence and relative abundance.

3.1.1.2 Bacteria Monitoring at Swimming Beaches

The District has cooperated with the Nebraska Department of Environmental Quality (NDEQ) to monitor bacteria levels present at swimming beaches and major recreational use areas at the Gavins Point project over the past 4 years. Four swimming beaches and one recreational area on Gavins Point Reservoir and one swimming beach on Lake Yankton were monitored. Weekly grab samples were collected from May through September and analyzed for fecal coliform and *E. coli* bacteria. The bacteria monitoring was conducted to meet a 6-hour holding time for collected samples.

3.1.1.3 Intensive Water Quality Surveys

3.1.1.3.1 Fort Peck Reservoir (Fort Peck Lake)

The Omaha District conducted intensive water quality surveys at Fort Peck Reservoir during 2004 and 2005. The monitoring objectives of the intensive surveys were to collect water quality data to spatially describe water quality conditions present in Fort Peck Reservoir during the late spring and summer, and to collect information to facilitate the application of the CE-QUAL-W2 hydrodynamic and water quality model. As part of the intensive surveys, six reservoir sites and three inflow sites were monitored. The six reservoir sites were located in deepwater areas on the Missouri River and Dry Creek Arms of Fort Peck Reservoir. The inflow sites were located on the Missouri River, Musselshell River, and Big Dry Creek and were meant to represent water quality conditions of water flowing into Fort Peck Reservoir. Monthly samples at the reservoir and inflow sites were collected from June through September.

Water quality monitoring at the reservoir sites included field measurements for depth profiling and water transparency, and collection of near-surface and near-bottom water samples for laboratory

analysis. Monitoring at the inflow sites included field measurements and collection of a near-surface water sample for laboratory analysis. Reservoir depth profiles in 1-meter increments were recorded for temperature, dissolved oxygen, pH, conductivity, ORP, chlorophyll *a*, and turbidity. Field measurements taken at the inflow sites included temperature, dissolved oxygen, pH, conductivity, and turbidity. Near-surface and near-bottom grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, total Kjeldahl nitrogen, total phosphorus, orthophosphorus, dissolved total phosphorus, total suspended solids, total dissolved solids, total organic carbon, sulfate, iron (total and dissolved), and manganese (total and dissolved). The near-surface samples were also analyzed for chlorophyll *a* and phytoplankton taxa occurrence and relative abundance.

3.1.1.3.2 Garrison Reservoir (Lake Sakakawea)

The Omaha District conducted intensive water quality surveys at Garrison Reservoir during 2003, 2004, and 2005. The monitoring objectives of the intensive surveys were to collect water quality data to spatially describe water quality conditions present in the reservoir during the summer, evaluate the occurrence of coldwater habitat, and collect information to facilitate the application of the CE-QUAL-W2 hydrodynamic and water quality model. As part of the intensive surveys, up to eight reservoir sites and two inflow sites were monitored. The eight reservoir sites were relatively equally spaced in deepwater areas from Garrison Dam to White Earth Bay (i.e., 12 miles above the Four Bears Bridge near New Town, ND). The inflow sites were located on the Missouri and Little Missouri Rivers and were meant to represent water quality conditions of water flowing into Garrison Reservoir. Monthly to biweekly samples at the reservoir and inflow sites were collected during June through September.

Water quality monitoring at the reservoir sites included field measurements for depth profiling and water transparency, and collection of near-surface and near-bottom water samples for laboratory analysis. Monitoring at the inflow sites included field measurements and collection of a near-surface water sample for laboratory analysis. Reservoir depth profiles in 1-meter increments were recorded for temperature, dissolved oxygen, pH, conductivity, ORP, chlorophyll *a*, and turbidity. Field measurements taken at the inflow sites included temperature, dissolved oxygen, pH, conductivity, and turbidity. Near-surface and near-bottom grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, total Kjeldahl nitrogen, total phosphorus, ortho-phosphorus, dissolved total phosphorus, total suspended solids, total dissolved solids, total organic carbon, sulfate, iron (total and dissolved), and manganese (total and dissolved). The near-surface samples were also analyzed for chlorophyll *a* and phytoplankton taxa occurrence and relative abundance.

3.1.1.3.3 Oahe Reservoir (Lake Oahe)

The Omaha District conducted an intensive water quality survey at Oahe Reservoir during 2005. The monitoring objectives of the intensive survey were to collect water quality data to spatially describe water quality conditions present in the reservoir during the summer and to collect information to facilitate the application of the CE-QUAL-W2 hydrodynamic and water quality model. As part of the intensive surveys, seven reservoir sites and two inflow sites were monitored. The seven reservoir sites were relatively equally spaced in deepwater areas from Oahe Dam to near Mobridge, SD. The inflow sites were located on the Missouri and Cheyenne Rivers and were meant to represent water quality conditions of water flowing into Oahe Reservoir. Monthly samples at the reservoir and inflow sites were collected during June through September.

Water quality monitoring at the reservoir sites included field measurements for depth profiling and water transparency; and collection of near-surface and near-bottom water samples for laboratory analysis. Monitoring at the inflow sites included field measurements and collection of a near-surface water sample for laboratory analysis. Reservoir depth profiles in 1-meter increments were recorded for

temperature, dissolved oxygen, pH, conductivity, ORP, chlorophyll a, and turbidity. Field measurements taken at the inflow sites included temperature, dissolved oxygen, pH, conductivity, and turbidity. Near-surface and near-bottom grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, total Kjeldahl nitrogen, total phosphorus, ortho-phosphorus, dissolved total phosphorus, total suspended solids, total dissolved solids, total organic carbon, sulfate, iron (total and dissolved), and manganese (total and dissolved). The near-surface samples were also analyzed for chlorophyll a and phytoplankton taxa occurrence and relative abundance.

3.1.2 MAINSTEM SYSTEM POWER PLANTS

As part of the operation of the Mainstem System power plants, water is drawn from the intake structure of each dam and piped through the power plant in a "raw water" supply line that is tapped for various uses. The "raw water" supply line is an open ended, flow-through system (i.e., water is continually discharged). A monitoring station, that measures water quality conditions of water drawn from near the start of the "raw water" supply line, has been irregularly maintained at each of the power plants over the past several years. Water quality monitoring has consisted of year-round, hourly measurements of temperature, dissolved oxygen, pH, and conductivity through the use of a data-logger. Recently, monthly grab samples (year-round) have also been collected and analyzed for alkalinity, nitrate/nitrite, total ammonia, total Kjeldahl nitrogen, total phosphorus, ortho-phosphorus, total suspended solids, total dissolved solids, total organic carbon, sulfate, pesticides, and various metals. The rate of dam discharge when measurements and samples were taken was determined from power plant records. The water quality conditions measured in the "raw water" supply lines of the mainstem power plants are believed to represent the water quality conditions present in the reservoirs near the dam intakes and in the tailwaters (i.e., Missouri River) immediately downstream of the dam.

3.1.3 MISSOURI RIVER FROM FORT RANDALL DAM TO RULO, NEBRASKA

Since 2003, the District has cooperated with the State of Nebraska (NDEQ) to monitor ambient water quality conditions along the Missouri River from Fort Randall Dam to Rulo, Nebraska. Fixed-station monitoring has occurred at the following nine sites: Fort Randall Dam tailwaters; near Verdel, NE; Gavins Point Dam tailwaters; near Maskell, NE; near Ponca, NE; at Decatur, NE; at Omaha, NE; at Nebraska City, NE; and at Rulo, NE. Water quality monitoring consisted of collecting near-surface grab samples monthly from October through March and biweekly from April through September. When feasible, the grab samples were collected in the thalweg of the main channel. When boat operation was not feasible (e.g., winter ice conditions, staff unavailable, etc.), the grab samples were collected from the bank in an area of fast current. The collected grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, total Kjeldahl nitrogen, total phosphorus, total suspended solids, total organic carbon, chemical oxygen demand, chloride, pesticides, and various metals. Field measurements taken at the time of sample collection included temperature, pH, dissolved oxygen, conductivity, and turbidity.

3.1.4 MAINSTEM SYSTEM ANCILLARY LAKES – LAKE YANKTON, LAKE POCASSE, AND LAKE AUDUBON

Lake Yankton, Lake Pocasse, and Lake Audubon are ancillary lakes to the Mainstem System reservoirs respectively at the Gavins Point, Oahe, and Garrison projects. Water quality monitoring at these three lakes has been sporadic in the past. The Omaha District will initiate ambient water quality monitoring at the lakes in 2006 as part of a 3-year rotational monitoring cycle. Scheduled monitoring includes monthly sampling (May through September) at a near-dam deepwater location. Water quality monitoring includes field measurements for depth profiling and water transparency and collection of near-surface and near-bottom water samples for laboratory analysis. Depth profiles in 1-meter increments are to be taken for temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll a. Near-

surface and near-bottom grab samples are to be analyzed for alkalinity, nitrate/nitrite, total ammonia, Kjeldahl nitrogen, total phosphorus, orthophosphorus, total suspended solids, total organic carbon, chlorophyll *a*, pesticides, and various metals.

3.2 TRIBUTARY PROJECTS

3.2.1 COLORADO TRIBUTARY RESERVOIRS

The District has not conducted water quality monitoring at any of the three Corps project reservoirs in Colorado since 2002. At each of these reservoirs (i.e., Bear Creek, Chatfield, and Cherry Creek), local Watershed Authorities have been established to improve and protect water quality. As part of these efforts, the Watershed Authorities have established extensive water quality monitoring networks at each of the three reservoirs. After reviewing the water quality monitoring efforts of the three Watershed Authorities, the District felt that its water quality information needs can be met though the use of the water quality data collected through the efforts of the Watershed Authorities. Assessments of recent water quality conditions at the three Colorado project reservoirs are based on the data collected by the local Watershed Authorities.

3.2.2 NEBRASKA TRIBUTARY RESERVOIRS

3.2.2.1 Ambient Monitoring of Reservoir Water Quality Conditions

Fixed station ambient monitoring has occurred at the Nebraska tributary reservoirs over the past 30 years. Since 2003, the Omaha District has cooperated with the NDEQ to monitor ambient water quality conditions at all the Papillion Creek tributary reservoirs (i.e., Glenn Cunningham, Standing Bear, Wehrspann, and Ed Zorinsky) and Salt Creek tributary reservoirs (i.e., Bluestem, Branched Oak, Conestoga, East Twin, Holmes, Olive Creek, Pawnee, Stagecoach, Wagon Train, West Twin, and Yankee Hill). Recent water quality monitoring has been curtailed at the Holmes and Yankee Hill Reservoirs due to draw-downs for renovations.

Ambient water quality monitoring at the Nebraska tributary reservoirs included monthly sampling (May through September) at near-dam and mid-reservoir deepwater locations. Water quality monitoring at the near-dam location included field measurements for depth profiling and water transparency, and collection of near-surface and near-bottom grab samples for laboratory analysis. Water quality monitoring at the mid-reservoir location included field measurements for depth profiling and water transparency. Depth profiles in 1-meter increments were determined for temperature, dissolved oxygen, pH, conductivity, and ORP. Near-surface and near-bottom grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, Kjeldahl nitrogen, total phosphorus, orthophosphorus, total suspended solids, total organic carbon, chlorophyll *a*, pesticides, and various metals. During 2005, near-surface samples were also analyzed for the cyanobacteria toxin microcystins.

3.2.2.2 Bacteria Monitoring at Swimming Beaches

The Omaha District has cooperated with the NDEQ to monitor bacteria levels present at swimming beaches and major recreational use areas at the Nebraska tributary reservoirs over the past 4 years. Reservoirs that were sampled include: Glenn Cunningham, Bluestem, Branched Oak, Conestoga, Pawnee, and Wagon Train. Weekly grab samples were collected from May to September and analyzed for fecal coliform and *E. coli* bacteria. The bacteria monitoring was conducted to meet a 6-hour holding time for collected samples.

3.2.2.3 <u>Inflow Monitoring During Runoff Conditions</u>

Since 2003, the District has cooperated with the NDEQ to monitor water quality conditions of major inflows under runoff conditions at all the Nebraska tributary reservoirs. Up to six runoff events from April through September were sampled annually at each of the reservoirs. Near-surface runoff grab samples were collected from a bridge or stream bank and analyzed for suspended solids, total Kjeldahl nitrogen, nitrate/nitrate, total ammonia, total phosphorus, alachlor, atrazine, and metolachlor.

3.2.3 NORTH DAKOTA TRIBUTARY RESERVOIRS

The District has monitored ambient water quality conditions over the past 30 years at the two Corps tributary reservoirs in North Dakota – Bowman-Haley and Pipestem. During the past 5 years, ambient monitoring has occurred every year except 2005. Ambient water quality monitoring at Bowman-Haley and Pipestem Reservoirs is now on a 3-year rotating cycle with the next ambient monitoring scheduled for 2007. The ambient monitoring included monthly sampling (May through September) at near-dam and mid-reservoir deepwater locations. Water quality monitoring at the near-dam location included field measurements for depth profiling and water transparency and collecting near-surface and near-bottom water samples for laboratory physicochemical analysis. Water quality monitoring at the mid-reservoir location included field measurements for depth profiling and water transparency. Depth profiles in 1-meter increments were determined for temperature, dissolved oxygen, pH, conductivity, and ORP. Near-surface and near-bottom grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, Kjeldahl nitrogen, total phosphorus, ortho-phosphorus, total suspended solids, total organic carbon, chlorophyll *a*, pesticides, and various metals.

3.2.4 SOUTH DAKOTA TRIBUTARY RESERVOIRS

During the past 5 years, the District conducted water quality monitoring at the two Corps tributary project reservoirs in South Dakota (i.e., Cold Brook and Cottonwood Springs) in 2001, 2002, and 2003. Ambient water quality monitoring at the two reservoirs is now on a 3-year rotating cycle with the next ambient monitoring scheduled for 2008. Ambient water quality monitoring was scheduled for 2005, but was cancelled due low water conditions and access problems. Scheduled ambient water quality monitoring includes monthly sampling (May through September) at near-dam and mid-reservoir deepwater locations. Water quality monitoring at the near-dam location includes field measurements for depth profiling and water transparency and collecting near-surface and near-bottom water samples for laboratory physicochemical analysis. Water quality monitoring at the mid-reservoir location includes field measurements for depth profiling and water transparency. Depth profiles in 1-meter increments are determined for temperature, dissolved oxygen, pH, conductivity, and ORP. Near-surface and near-bottom grab samples are analyzed for alkalinity, nitrate/nitrite, total ammonia, Kjeldahl nitrogen, total phosphorus, ortho-phosphorus, total suspended solids, total organic carbon, chlorophyll *a*, pesticides, and various metals.

4 WATER QUALITY ASSESSMENT METHODS

4.1 RESERVOIR WATER QUALITY

4.1.1 Existing Water Quality Conditions

4.1.1.1 Statistical Summary of Collected Water Quality Data and Water Quality Standards Attainment

Summary statistics were calculated for water quality data collected during the past 5 years (i.e., 2001 through 2005), and the data were compared to applicable water quality standards established by the appropriate Tribes and States pursuant to the Federal CWA. Tables were constructed that list the parameters measured; number of observations; and the mean, median, minimum, and maximum of the data collected. The constructed tables also list the water quality standards criteria applicable to the individual parameters and the frequency that these criteria were not met.

4.1.1.2 Phytoplankton Community

Assessment of the phytoplankton community was based on grab samples that were analyzed by a contract laboratory. Laboratory analyses consisted of identification of phytoplankton taxa to the lowest practical level and quantification of taxa biovolume. These results were used to determine the relative abundance of phytoplankton taxa at the division level based on the measured biovolumes.

4.1.1.3 Summer Reservoir Stratification and Hypolimnetic Dissolved Oxygen Conditions

Existing summer thermal stratification and hypolimnetic dissolved oxygen conditions were evaluated based on monitoring results obtained during the past 5 years (i.e., 2001 to 2005). The data evaluated consisted of depth-profile measurements collected during the period July through September at near-dam, deepwater monitoring sites. Temperature and dissolved oxygen depth profiles were constructed and plotted for evaluation.

4.1.1.4 Trophic State

A trophic state index (TSI) was calculated, as described by Carlson (1977). TSI values were determined from Secchi disk transparency, total phosphorus, and chlorophyll *a* measurements. Values for these three parameters were converted to an index number ranging from 0 to 100 according to the following equations:

$$\mathrm{TSI(Secchi\ Depth)} = \mathrm{TSI(SD)} = 10[6 - (\ln SD/\ln 2)]$$
$$\mathrm{TSI(Chlorophyll}\ a) = \mathrm{TSI(Chl)} = 10[6 - ((2.04-0.68 \ln Chl)/\ln 2)]$$
$$\mathrm{TSI(Total\ Phosphorus)} = \mathrm{TSI(TP)} = 10[6 - (\ln (48/TP)/\ln 2)]$$

Accurate TSI values from total phosphorus depend on the assumptions that phosphorus is the major limiting factor for algal growth and that the concentrations of all forms of phosphorus present are a function of algal biomass. Accurate TSI values from Secchi disk transparency depend on the assumption that water clarity is primarily limited by phytoplankton biomass. Carlson indicates that the chlorophyll TSI value may be a better indicator of a lake's trophic conditions during mid-summer when algal productivity is at its maximum, while the total phosphorus TSI value may be a better indicator in the spring and fall when algal biomass is below its potential maximum. Calculation of TSI values from data

collected from a lake's epilimnion during summer stratification provide the best agreement between all of the index parameters and facilitate comparisons between lakes. Carlson states that care must be taken if a TSI average score is calculated from the three individual parameter TSI values. If significant differences exist between parameter TSI values, the calculated average value may not be indicative of the trophic condition estimated by the individual parameter values. With this consideration, a TSI average value [TSI(Avg)] calculated as the average of the three individually determined TSI values [i.e., TSI(SD), TSI(Chl), and TSI(TP)] is used by the District as an overall indicator of a reservoir's trophic state. The District uses the criteria defined in Table 4.1 for determining reservoir trophic status from TSI values.

In addition to classifying lakes, the TSI can serve as an internal check on the assumptions about the relationships among various components of a lake's ecosystem. Carlson states that the three TSI parameters, when transformed to the trophic scale, should have similar values. Any divergence from this value by one or more of the parameters may provide insights into a lake's water quality dynamics (e.g., is the lake phosphorus limited, is water clarity limited by algae or nonalgal particulate matter, etc.)

Existing trophic conditions were assessed at District project reservoirs based on monitoring results obtained during the past 5 years (i.e., 2001 to 2005). The data evaluated consisted of Secchi depth measurements and total phosphorus and chlorophyll *a* analytical results obtained during the period May through September. TSI values were calculated and compared to the criteria given in Table 4.1.

Table 4.1. Reservoir trophic status based on calculated TSI values.

TSI	Trophic Condition
0-35	Oligotrophic
36-50	Mesotrophic
51-55	Moderately Eutrophic
56-65	Eutrophic
66-100	Hypereutrophic

4.1.2 WATER QUALITY TRENDS

Surface water quality trends were assessed by evaluating water clarity (i.e. Secchi depth), total phosphorus, chlorophyll *a* and calculated TSI(Avg) values from monitoring results obtained at long-term, fixed station ambient monitoring sites for the period 1980 to 2005.

4.2 WATER QUALITY AT THE MISSOURI RIVER MAINSTEM POWER PLANTS

4.2.1 STATISTICAL SUMMARY OF COLLECTED WATER QUALITY DATA AND WATER QUALITY STANDARDS ATTAINMENT

Summary statistics were calculated for water quality data collected during the "Water Year" October 1, 2004 to September 30, 2005, and the data were compared to applicable water quality standards established by the appropriate Tribes and States pursuant to the Federal CWA. Tables were constructed that list the parameters measured; number of observations; and the mean, median, minimum, and maximum of the data collected. The constructed tables also list the water quality standards criteria applicable to the individual parameters and the frequency that these criteria were not met.

4.2.2 TEMPERATURE, DISSOLVED OXYGEN, AND DAM DISCHARGE TIME-SERIES PLOTS

Time-series plots of water quality conditions measured in the "raw water" supply lines and dam discharge rates were constructed from hourly data to describe and evaluate temporal variation. Time-series plots of water temperature and dam discharge and of dissolved oxygen and dam discharge were constructed for the period October 1, 2004 through September 30, 2005

4.3 LOWER MISSOURI RIVER WATER QUALITY

4.3.1 STATISTICAL SUMMARY OF COLLECTED WATER QUALITY DATA AND WATER QUALITY STANDARDS ATTAINMENT

Summary statistics were calculated for water quality data collected during the 3-year period 2003 through 2005, and the data were compared to applicable water quality standards established by the appropriate Tribes and States pursuant to the Federal CWA. Tables were constructed that list the parameters measured; number of observations; and the mean, median, minimum, and maximum of the data collected. The constructed tables also list the water quality standards criteria applicable to the individual parameters and the frequency that these criteria were not met.

4.3.2 LONGITUDINAL VARIATION IN WATER QUALITY

Box plots where constructed to display the longitudinal variability in water quality conditions that were monitored in the Missouri River from Fort Randall Dam to Rulo, NE during the 3-year period 2003 through 2005. For comparison purposes, the box plots for the monitoring sites were arranged relative to their respective location, in river mileage (RM), from upstream to downstream (i.e., RM880, RM851, RM811, RM774, RM753, RM691, RM619, RM563, and RM498).

5 MAINSTEM SYSTEM

5.1 BACKGROUND INFORMATION

The Missouri River Mainstem System (Mainstem System) is comprised of six dams and reservoirs constructed by the Corps on the Missouri River and, where present, the free-flowing Missouri River downstream of the project dams. The six reservoirs impounded by the dams contain about 73.4 million acre-feet (MAF) of storage capacity and, at normal pool, an aggregate water surface area of about 1 million acres. The six dams and reservoirs in an upstream to downstream order are: Fort Peck Dam and Reservoir (Montana), Garrison Dam and Reservoir (North Dakota), Oahe Dam (South Dakota) and Oahe Reservoir (North and South Dakota), Big Bend Dam and Reservoir (South Dakota), Fort Randall Dam and Reservoir (South Dakota), and Gavins Point Dam and Reservoir (South Dakota and Nebraska). The water in storage at the all Mainstem System reservoirs at the end of 2005 (i.e., December 2005) was 36.0 MAF which is 49 percent of the total system storage volume. Drought conditions in the upper Missouri River Basin since 2000 have reduced the water stored in the upper three Mainstem System reservoirs to record low levels.

5.1.1 REGULATION OF THE MAINSTEM SYSTEM

The Mainstem System is a hydraulically and electrically integrated system that is regulated to obtain the optimum fulfillment of the multipurpose benefits for which the dams and reservoirs were authorized and constructed. The Congressionally authorized purposes of the Mainstem System are flood control, navigation, hydropower, water supply, water quality, irrigation, recreation, and fish and wildlife (including threatened and endangered species). The Mainstem System is operated under the guidelines described in the Missouri River Mainstem System Master Water Control Manual, (Master Manual) (USACE-RCC, 2004). The Master Manual details regulation for all authorized purposes as well as emergency regulation procedures in accordance with the authorized purposes.

Mainstem System regulation is, in many ways, a repetitive annual cycle that begins in late winter with the onset of snowmelt. The annual melting of mountain and plains snowpacks along with spring and summer rainfall produces the annual runoff into the Mainstem System. In a typically year mountain snowpack, plains snowpack, and rainfall events respectively contribute 50, 25, and 25% of the annual runoff to the Mainstem System. After reaching a peak, usually during July, the amount of water stored in the Mainstem System declines until late in the winter when the cycle begins anew. A similar pattern may be found in rates of releases from the Mainstem System, with the higher levels of flow from mid-March to late November, followed by low rates of winter discharge from late November until mid-March, after which the cycle repeats.

To maximize the service to all the authorized purposes, given the physical and authorization limitations of the Mainstem System, the total storage available in the system is divided into four regulation zones that are applied to the individual reservoirs. These four regulation zones are: 1) Exclusive Flood Control Zone, 2) Annual Flood Control and Multiple Use Zone, 3) Carryover Multiple Use Zone, and 4) Permanent Pool Zone.

5.1.1.1 <u>Exclusive Flood Control Zone</u>

Flood control is the only authorized purpose that requires empty space in the reservoirs to achieve the objective. A top zone in each Mainstem System reservoir is reserved for use to meet the flood control

requirements. This storage space is used only for detention of extreme or unpredictable flood flows and is evacuated as rapidly as downstream conditions permit, while still serving the overall flood control objective of protecting life and property. The Exclusive Flood Control Zone encompasses 4.7 MAF and represents the upper 6 percent of the total Mainstem System storage volume. This zone, from 73.4 MAF down to 68.7 MAF, is normally empty. The four largest reservoirs, Fort Peck, Garrison, Oahe, and Fort Randall, contain 97 percent of the total storage reserved for the Exclusive Flood Control Zone.

5.1.1.2 Annual Flood Control and Multiple Use Zone

An upper "normal operating zone" is reserved annually for the capture and retention of runoff (normal and flood) and for annual multiple-purpose regulation of this impounded water. The Mainstem System storage capacity in this zone is 11.7 MAF and represents 16 percent of the total system storage volume. This storage zone, which extends from 68.7 MAF down to 57.0 MAF, will normally be evacuated to the base of this zone by March 1 to provide adequate storage capacity for capturing runoff during the next flood season. On an annual basis, water will be impounded in this zone, as required to achieve the system flood control purpose, and also be stored in the interest of general water conservation to serve all the other authorized purposes. The evacuation of water from the Annual Flood Control and Multiple Use Zone is scheduled to maximize service to the authorized purposes that depend on water from the system. Scheduling releases from this zone is limited by the flood control objective in that the evacuation must be completed by the beginning of the next flood season. This is normally accomplished as long as the evacuation is possible without contributing to serious downstream flooding. Evacuation is, therefore, accomplished mainly during the summer and fall because Missouri River ice formation and the potential for flooding from higher release rates limit release rates during the December through March period.

5.1.1.3 Carryover Multiple Use Zone

The Carryover Multiple Use Zone is the largest storage zone extending from 57.0 MAF down to 18.0 MAF and represents 53 percent of the total system storage volume. Serving the authorized purposes during an extended drought is an important regulation objective of the Mainstem System. The Carryover Multiple Use Zone provides a storage reserve to support authorized purposes during drought conditions. Providing this storage is the primary reason the upper three reservoirs of the Mainstem System are so large compared to other Federal water resource projects. The Carryover Multiple Use Zone is often referred to as the "bank account" for water in the Mainstem System because of its role in supporting authorized purposes during critical dry periods when the storage in the Annual Flood Control and Multiple Use Zone is exhausted. Only the reservoirs at Fort Peck, Garrison, Oahe, and Fort Randall have this storage as a designated storage zone. The three larger reservoirs (Fort Peck, Garrison, and Oahe) provide water to the Mainstem System during drought periods to provide for authorized purposes. The storage space assigned to this zone in Fort Randall Reservoir serves a different purpose. It is normally evacuated each year during the fall season to provide recapture space for upstream winter power releases. The recapture results in complete refill of Fort Randall Reservoir during the winter months. During drought periods, the three smaller projects (i.e., Fort Randall, Big Bend, and Gavins Point) reservoir levels are maintained at the same elevation they would be at if runoff conditions were normal.

5.1.1.4 Permanent Pool Zone

The Permanent Pool Zone is the bottom zone that is intended to be permanently filled with water. The zone provides for future sediment storage capacity and maintenance of minimum pool levels for power heads, irrigation diversions, water supply, recreation, water quality, and fish and wildlife. A drawdown into this zone is generally not scheduled except in unusual conditions. The Mainstem System

storage capacity in this storage zone is 18.0 MAF and represents 25 percent of the total storage volume. The Permanent Pool Zone extends from 18.0 MAF down to 0 MAF.

5.1.2 WATER CONTROL PLAN FOR THE MAINSTEM SYSTEM

Variations in runoff into the Mainstem System necessitates varied regulation plans to accommodate the multipurpose regulation objectives. The two primary high-risk flood seasons are the plains snowmelt and rainfall season extending from late February through April, and the mountain snowmelt and rainfall period extending from May through July. Also, the winter ice-jam flood period extends from mid-December through February. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The power needs during the winter are supplied primarily with Fort Peck and Garrison Dam releases and the peaking capacity of Oahe and Big Bend Dams. During the spring and summer period, releases are normally geared to navigation and flood control requirements, and primary power loads are supplied using the four lower dams. During the fall when power needs diminish, Fort Randall is normally drawn down to permit generation during the winter period when Oahe and Big Bend peaking-power releases refill the reservoir. The normal 8-month navigation season extends from April 1 through November 30, during which time Mainstem System releases are increased to meet downstream target flows in combination with downstream tributary inflows. Winter releases after the close of the navigation season are much lower and vary depending on the need to conserve or evacuate storage volumes, downstream ice conditions permitting. Releases and pool fluctuations for fish spawning management generally occur from April 1 through June. Two threatened and endangered bird species, piping plover (*Charadrius melodus*) and least tern (*Sterna antillarum*), nest on “sandbar” areas from early May through mid-August. Other factors may vary widely from year to year, such as the amount of water-in-storage and the magnitude and distribution of inflow received during the coming year. All these factors will affect the timing and magnitude of Mainstem System releases. The gain or loss in the water stored at each reservoir must also be considered in scheduling the amount of water transferred between reservoirs to achieve the desired storage levels and to generate power. These items are continually reviewed as they occur and are appraised with respect to the expected range of regulation.

5.1.3 OCCURRENCE OF “TWO-STORY” FISHERIES

Fort Peck, Garrison, and Oahe Reservoirs maintain “two-story” fisheries that are comprised of warmwater and coldwater species. The ability of the reservoirs to maintain “two-story” fisheries is due to their thermal stratification in the summer into a colder bottom region and a warmer surface region. Warmwater species present in the reservoirs that are recreationally important include walleye (*Sander vitreus*), sauger (*Sander canadensis*), northern pike (*Esox lucius*), smallmouth bass (*Micropterus dolomieu*), catfish (*Ictalurus spp.*), and yellow perch (*Perca flavescens*). The Chinook salmon (*Oncorhynchus tshawytscha*) is a coldwater species of recreational importance that is maintained in all three reservoirs through regular stocking. Other coldwater species present are rainbow smelt (*Osmerus mordax*) in Oahe and Garrison Reservoirs, and lake cisco (*Coregonus artedi*) in Fort Peck Reservoir. Both species are important forage fish that are utilized extensively by all recreational species in the respective reservoirs. Maintaining healthy populations of these forage fish are important to maintaining the recreational fisheries in the three reservoirs.

The occurrence of coldwater habitat in Fort Peck, Garrison, and Oahe Reservoirs is directly dependent on each reservoir’s annual thermal regime. Early in the winter ice-cover period, the entire reservoir volume will be supportive of coldwater habitat. As the winter ice-cover period continues, lower dissolved oxygen concentrations will likely occur near the bottom as organic matter decomposes and reservoir mixing is prevented by ice cover. As dissolved oxygen concentrations in the near-bottom water

fall below 5 mg/l, coldwater habitat will not be supported. During the spring isothermal period, water temperatures and dissolved oxygen levels in the entire reservoir volume will be supportive of coldwater habitat. During the early-summer warming period, the epilimnion will become non-supportive of coldwater habitat. During mid-summer when the reservoirs are experiencing maximum thermal stratification, water temperatures will only be supportive of coldwater habitat in the hypolimnion. Theoretically, coldwater habitat should remain stable during this period unless degradation of dissolved oxygen concentrations near the reservoir bottom becomes non-supportive of coldwater habitat. The most crucial period for the support of coldwater habitat in the three reservoirs is when they begin to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion will continue to decrease while the expanding epilimnion may not yet be cold enough to be supportive of coldwater habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and pinching off coldwater habitat from below. This situation will continue to worsen until the epilimnion cools enough to be supportive of coldwater habitat. When fall turnover occurs, dissolved oxygen concentrations at all depths will be near saturation and supportive of coldwater habitat. However, depending on the hydrologic conditions of the reservoir, the isothermal temperature at the beginning of fall turnover may not be supportive of all coldwater habitats. This situation will continue to occur until the isothermal temperature cools to suitable temperatures, at which time the entire reservoir volume will be supportive of coldwater habitat.

5.2 FORT PECK

5.2.1 BACKGROUND INFORMATION

Fort Peck Dam is located on the Missouri River at river mile (RM) 1771.5 in northeastern Montana, 17 miles southeast of Glasgow, Montana. The closing of Fort Peck Dam in 1937 resulted in the formation of Fort Peck Reservoir (Fort Peck Lake). When full, the reservoir is 134 miles long, covers 246,000 acres, and has 1,520 miles of shoreline. Table 5.1 summarizes how the surface area, volume, mean depth, and retention time of Fort Peck Reservoir vary with pool elevations. Due to ongoing drought conditions, the reservoir, as of December 2005, was more than 32 feet below the pool elevation of 2234 ft-msl, which is the top of the Carryover Multiple Use Zone. Major inflows to the reservoir are the Missouri River, Musselshell River, and Big Dry Creek. Water discharged through Fort Peck Dam for power production is withdrawn from Fort Peck Reservoir at elevation 2095 ft-msl – approximately 65 feet above the reservoir bottom.

Fort Peck was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. The power plant has five generating units that produce an annual average 1.10 million mega-watt hours of electricity, valued in excess of $10 million in revenue. Habitat for one endangered species, pallid sturgeon (*Scaphirhynchus albus*), occurs within the project area. The reservoir is used as a water supply by the town of Fort Peck, Montana and by numerous individual cabins in the area. Fort Peck Reservoir is an important recreational resource and a major visitor destination in Montana.

The State of Montana has assigned Fort Peck Reservoir a B-3 classification in the State’s water quality standards. As such, the reservoir is to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply. Pursuant to Section 303(d) of the Federal CWA, Montana has placed Fort Peck Reservoir on the State’s list of impaired waters citing impairment to the uses of drinking water supply and primary contact recreation due to the pollutants of lead, mercury, metals, and noxious aquatic plants. The identified sources of these pollutants are agriculture, resource extraction, abandoned

mining, atmospheric deposition, debris, and bottom deposits. The State of Montana has also issued a fish consumption advisory for the reservoir due to mercury concerns.

Table 5.1. **S**urface area, volume, mean depth, and retention time of Fort Peck Reservoir at different pool elevations.

Pool Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
2250	245,898	18,687,731	76.0	2.72
2245	238,094	17,474,394	73.4	2.54
2240	226,691	16,309,409	71.9	2.37
2235	214,031	15,208,569	71.1	2.21
2230	200,563	14,169,579	70.6	2.06
2225	187,984	13,202,148	70.2	1.92
2220	179,404	12,236,952	68.2	1.78
2215	172,112	11,407,020	66.3	1.66
2210	164,592	10,565,907	64.2	1.54
2205	157,232	9,761,001	62.1	1.42
2200	149,653	8,993,723	60.1	1.31
2195	142,016	8,264,516	58.2	1.20
2190	134,099	7,573,749	56.5	1.10
2185	126,382	6,923,345	54.8	1.01
2180	119,809	6,309,129	52.7	0.92
2175	113,166	5,725,330	50.6	0.83
2170	104,794	5,178,658	49.4	0.75
2165	96,624	4,677,236	48.4	0.68
2160	90,348	4,211,053	46.6	0.61

Average Annual Inflow (1967 through 2005) = 7.37 Million Acre-Feet
Average Annual Outflow: (1967 through 2005) = 6.87 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 2250-2246 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 2246-2234 ft-msl), Carryover Multiple Use Zone (elev. 2234-2160 ft-msl), and Permanent Pool Zone (elev. 2160-2030 ft-msl).

The Missouri River downstream of Fort Peck Dam has been assigned, in the State of Montana's water quality standards, a B-2 classification from the dam to the confluence of the Milk River, and a B-3 classification from the Milk River confluence to the Montana/North Dakota state line. Both B-2 and B-3 waters are to be maintained suitable for drinking, culinary and food processing purposes, after conventional treatment; bathing, swimming and recreation; waterfowl and furbearers; and agricultural and industrial water supply. In addition, B-2 waters are to maintain growth and marginal propagation of salmonid fishes and associated aquatic life, and B-3 waters are to maintain growth and propagation of non-salmonid fishes and associated aquatic life. The river is used as a water supply by several towns along the reach. Pursuant to Section 303(d) of the Federal CWA, Montana has placed the Missouri River downstream of Fort Peck Dam on the State's list of impaired waters citing impairment to the uses of aquatic life support, coldwater fishery – trout, and warmwater fishery due to the stressors of flow alteration, riparian degradation, thermal modifications, and other habitat alterations. The identified probable sources of these stressors are flow regulation/modification and hydromodification. No fish consumption advisory has been issued for the Missouri River downstream of Fort Peck dam by the State of Montana.

5.2.2 WATER QUALITY IN FORT PECK RESERVOIR

5.2.2.1 Existing Water Quality Conditions (2001 through 2005)

5.2.2.1.1 Statistical Summary and Water Quality Standards Attainment

Plate 1 summarizes the water quality conditions that were monitored in Fort Peck Reservoir from May through September during the 5-year period 2001 through 2005. A review of these results found no significant water quality concerns. The only water quality standards criteria exceeded were dissolved oxygen and mercury. One dissolved oxygen observation (4.2 mg/l) was below the 5 mg/l criterion for the protection of Class B-3 "warmwater" aquatic life. One total mercury measurement (0.06 ug/l) slightly exceeded the 0.05 ug/l criterion for human health protection.

5.2.2.1.2 Phytoplankton Community

Ten individual phytoplankton grab samples were collected from Fort Peck Reservoir at the near-dam, deepwater ambient monitoring site during 2004 and 2005 (Plate 2). The following six taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), and Pyrrophyta (Dinoflagellate Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Cyanobacteria/Chlorophyta > Cryptophyta/Pyrrophyta > Chrysophyta. The diatoms were generally the most abundant algae throughout the entire sampling period based on percent composition (Plate 2). The Shannon-Weaver genera diversity index calculated for the 10 collected phytoplankton samples ranged from 0.87 to 2.20 and averaged 1.49. Dominant phytoplankton species occurring in the 10 collected samples included the Bacillariophyta *Fragilaria spp.* (7 occasions), *Asterionella spp.* (4 occasions), *Cyclotella spp.* (3 occasions), *Aulacoseira spp.* (3 occasions), *Synedra spp.* (2 occasions), and *Stephanodiscus spp.* (2 occasions); Cryptophyta *Rhodomonas spp.* (2 occasions); Pyrrophyta *Peridinium spp.* (2 occasions) and *Ceratium spp.* (1 occasion); and Cyanobacteria *Aphanocapsa spp.* (1 occasion) (Plate 2). No detectable concentrations of the microcystins toxin were monitored at the near-dam, ambient monitoring site during 2005.

5.2.2.1.3 Summer Reservoir Stratification and Hypolimnetic Dissolved Oxygen Conditions

Existing summer thermal stratification and hypolimnetic dissolved oxygen conditions were assessed for Fort Peck Reservoir, based on monitoring results obtained at the near-dam, deepwater ambient monitoring site during the past 5 years (i.e., 2001 through 2005). Temperature and dissolved oxygen depth profiles were constructed from water quality data collected during the months of July, August, and September. A significant temperature-depth gradient occurred in the reservoir in the near-dam lacustrine area during the summer, with a thermocline becoming established at a depth of about 20 meters (Plate 3). Dissolved oxygen levels did not exhibit a large gradient with depth and tended toward an orthograde vertical distribution (Plate 4). During the period of 2001 through 2005, dissolved oxygen concentrations in the hypolimnion generally remained at or above 5 mg/l through the summer (Plate 3). At the near-dam, ambient monitoring site, one dissolved oxygen measurement below 5 mg/l occurred near the reservoir bottom from a profile measured on September 16, 2002.

The lowest dissolved oxygen value recorded in the hypolimnion during the 2-year period the intensive water quality survey has been conducted at Fort Peck Reservoir (i.e., 2004 to 2005) was 3.5 mg/l. This value was measured near the reservoir bottom in the Hell Creek area (i.e. RM 1805) on August 23, 2005. The Hell Creek area is in the transition zone of the reservoir.

5.2.2.1.4 Trophic State

Trophic State Index (TSI) values for Fort Peck Reservoir were calculated from monitoring data collected during the past 5 years (i.e. 2001 through 2005) at the near-dam, ambient monitoring site. Table 5.2 summaries the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area is in a mesotrophic state. During the 5-year period 2001 through 2005, the Fort Peck area has been under a period of extended drought, and the drought conditions may have had an influence on the water quality parameters used to calculate the TSI values.

Table 5.2. Summary of Trophic State Index (TSI) values calculated for Fort Peck Reservoir for the 5-year period 2001 through 2005.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	20	40	40	30	51
TSI(TP)	23	50	52	41	66
TSI(Chl)	15	40	40	40	46
TSI(Avg1)	23	44	44	35	51
TSI(Avg2)	12	46	47	40	52

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

5.2.2.2 <u>Water Quality Trends (1980 through 2005)</u>

Water quality trends over the period of 1980 to 2005 were determined for Fort Peck Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site. Plate 5 displays a scatter-plot of the collected data for the four parameters and a linear regression trend line. For the assessment period, it appears that Fort Peck Reservoir exhibited slightly decreasing transparency (i.e., decreasing Secchi depth) and slightly increasing levels of total phosphorus. There was no observed trend in chlorophyll *a* levels. Over the 26-year period, the reservoir has generally remained in a mesotrophic state. However, there appears to be a slight trend in the calculated TSI values that indicate the reservoir may be moving towards a moderately eutrophic condition (Plate 5).

5.2.3 WATER QUALITY AT THE FORT PECK POWER PLANT

5.2.3.1 <u>Statistical Summary and Water Quality Standards Attainment</u>

Plate 6 summarizes the water quality conditions that were monitored on water discharged through Fort Peck Dam during the 1-year period of October 2004 through September 2005. A review of these results indicated only one possible water quality concern regarding dissolved oxygen. The 1-day dissolved oxygen minimum criterion of 8.0 mg/l for the protection of coldwater B-2 early life stages was not met for 26% of the dissolved oxygen measurements. The 8.0 mg/l criterion is a water column concentration recommended to achieve an inter-gravel dissolved oxygen concentrations of 5.0 mg/l. For species that have early life stages exposed directly to the water column, the criterion is 5.0 mg/l. No dissolved oxygen measurements were below 5.0 mg/l. The B-2 classification of the Missouri River downstream of Fort Peck Dam only extends to the confluence of the Milk River, a distance of approximately 10 miles. Given the coldwater species present, the 5.0 mg/l water column dissolved

criterion may be appropriate for this reach. Also, the dissolved oxygen measurements below 8.0 mg/l tended to occur in later summer when the effects on early life stages are likely to be reduced. Therefore, the observed dissolved oxygen measurements below 8.0 mg/l are not believed to be a significant water quality concern at this time.

5.2.3.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Time series plots for temperature and dam discharge (Plates 7 – 10) and dissolved oxygen and dam discharge (Plates 11 – 14) were constructed for the period October 2004 through September 2005 based on monitoring of the water discharged through Fort Peck Dam. Water temperatures showed seasonal cooling in the October to December period (Plate 7), remained fairly constant through the January to March period (Plate 8), seasonal warming in the April to June period (Plate 9), and considerable variability during the July to September period (Plate 10). Dissolved oxygen levels exhibited a steady increase during the October to December period (Plate 11), remained fairly stable through the January to March period (Plate 12), and steadily declined through the April to September period (Plates 13 and 14). The steady increase in dissolved oxygen levels in the October to December period is attributed to increasing dissolved oxygen solubility as water temperatures steadily declined. The steady decrease in dissolved oxygen levels in the April to June period is attributed to decreasing dissolved oxygen solubility as water temperatures steadily increased. The decreasing dissolved oxygen in the July to September period is attributed to ongoing degradation of dissolved oxygen levels in the lower hypolimnion as the summer progressed. Water is withdrawn from Fort Peck Reservoir into the dam's power tunnels approximately 65 feet above the reservoir bottom. There appeared to be little correlation between discharge rates and measured water temperature and dissolved oxygen concentrations (Plates 7 – 14).

5.3 GARRISON

5.3.1 BACKGROUND INFORMATION

Garrison Dam is located in central North Dakota on the Missouri River at RM 1389.9, about 75 miles northwest of Bismarck, North Dakota and 11 miles south of the town of Garrison, North Dakota. Construction of the project began in 1946, and closure of Garrison Dam in 1953 resulted in the formation of Garrison Reservoir (Lake Sakakawea), which is the largest Corps reservoir in the United States. When full, the reservoir is 178 miles long, up to 6 miles wide, and has 1,884 miles of shoreline. The reservoir contains almost a third of the total storage capacity of the Mainstem System, nearly 24 million acre-feet (MAF). Table 5.3 summarizes how the surface area, volume, mean depth, and retention time of Garrison Reservoir vary with pool elevations. Due to ongoing drought conditions, the reservoir at the end of 2005 (i.e., December 2005) was about 25 feet below the pool elevation of 1837.5 ft-msl, which is the top of the Carryover Multiple Use Zone. Major inflows to the reservoir are the Missouri River, Yellowstone River, and Little Missouri River. Water discharged through Garrison Dam for power production is withdrawn from Garrison Reservoir at elevation 1672 ft-msl, approximately 2 feet above the reservoir bottom.

The reservoir and dam are authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. The power plant has five generating units that produce an annual average 2.34 million mega-watt hours of electricity, valued in excess of $25 million in revenue. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occurs within the project area. The reservoir is used as a water supply by some individual cabins and by the towns of Four Bears, Mandaree, Park City, Parshall, Riverdale, Trenton, Twin Buttes, and Williston, North Dakota. Garrison Reservoir is an important recreational resource and a major visitor destination in North Dakota.

Table 5.3. Surface area, volume, mean depth, and retention time of Garrison Reservoir at different pool elevations.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1855	384,480	24,203,180	63.0	1.52
1850	364,265	22,331,620	61.3	1.40
1845	344,460	20,558,360	59.7	1.29
1840	320,600	18,893,560	58.9	1.18
1835	296,210	17,355,220	58.6	1.09
1830	280,520	15,916,490	56.7	1.00
1825	263,525	14,556,980	55.2	0.91
1820	249,665	13,275,410	53.2	0.83
1815	235,600	12,061,430	51.2	0.76
1810	219,955	10,921,980	49.7	0.68
1805	204,453	9,861,138	48.2	0.62
1800	188,998	8,877,219	47.0	0.56
1795	173,070	7,973,682	46.1	0.50
1790	161,295	7,139,184	44.3	0.45
1785	148,759	6,364,791	42.8	0.40
1780	138,809	5,646,736	40.7	0.35
1775	128,261	4,979,890	38.8	0.31

Average Annual Inflow (1967 through 2005) = 16.69 Million Acre-Feet
Average Annual Outflow: (1967 through 2005) = 15.95 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1854-1850 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1850-1837.5 ft-msl), Carryover Multiple Use Zone (elev. 1837.5-1775 ft-msl), and Permanent Pool Zone (elev. 1775-1670 ft-msl).

Pursuant to the Federal CWA, the State of North Dakota has designated Garrison Reservoir as a Class 1 lake. As such, the reservoir is to be suitable for the propagation and/or protection of a coldwater fishery (i.e., salmonid fishes and associated aquatic biota); swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and for municipal or domestic use after appropriate treatment. Also pursuant to the CWA, the State of North Dakota has placed the reservoir on the State's Section 303(d) list of impaired waters citing impairment to the uses of fish and other aquatic biota and fish consumption due to the pollutants/stressors of low dissolved oxygen, water temperature, and methyl-mercury. The State of North Dakota has issued a fish consumption advisory for Garrison Reservoir due to mercury concerns.

5.3.2 WATER QUALITY IN GARRISON RESERVOIR

5.3.2.1 Existing Water Quality Conditions (2001 through 2005)

5.3.2.1.1 Statistical Summary and Water Quality Standards Attainment

Plate 15 summarizes the water quality conditions that were monitored in Garrison Reservoir from May through September during the 5-year period 2001 through 2005. A review of these results indicated possible water quality concerns regarding water temperature for the support of optimal coldwater habitat, dissolved oxygen levels for the support of aquatic biota, and lead levels. Water temperatures in the epilimnion of the reservoir regularly exceed 15°C in the summer, while temperatures in the hypolimnion

are less than 15°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses, and fall below 5.0 mg/l in late summer. Low dissolved oxygen conditions occur in the upstream reaches of the hypolimnion first and progress towards the dam. As the summer progresses, low dissolved oxygen conditions move up from the reservoir bottom into the mid and upper reaches of the hypolimnion. This pinching off of coldwater habitat threatens the occurrence of optimal coldwater habitat in the reservoir, especially under low pool levels during drought conditions. The lead criteria for the protection of aquatic life (chronic) and human health were respectively exceeded by two and one lead samples collected in 2001. Samples collected over the subsequent 4 years met water quality standards criteria, and it is not deemed a significant water quality concern at this time.

5.3.2.1.2 Phytoplankton Community

Ten individual phytoplankton grab samples were collected from Garrison Reservoir at the near-dam, deepwater ambient monitoring site during 2004 and 2005 (Plate 16). The following six taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), and Pyrrophyta (Dinoflagellate Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta/Cyanobacteria/Cryptophyta > Pyrrophyta/Chrysophyta. The diatoms were the most abundant algae throughout the entire sampling period based on percent composition (Plate 16). The Shannon-Weaver genera diversity index calculated for the 10 collected phytoplankton samples ranged from 0.46 to 1.93 and averaged 1.39. Dominant phytoplankton species occurring in the 10 collected samples included the Bacillariophyta *Fragilaria spp.* (7 occasions), *Asterionella spp.* (5 occasions), *Cyclotella spp.* (2 occasions), *Synedra* spp. (1 occasion), *Tabellaria spp*. (1 occasion), *Stephanodiscus spp*. (1 occasion), and *Melosira spp.* (1 occasion); Chlorophyta *Chlamydomonas spp.* (2 occasions); Cryptophyta *Rhodomonas spp.* (5 occasions) and *Cryptomonas spp.* (1 occasion); Pyrrophyta *Peridinium spp.* (1 occasion) and *Ceratium spp.* (1 occasion); and Cyanobacteria *Aphanocapsa spp*. (1 occasion) (Plate 16). No detectable concentrations of the microcystins toxin were monitored at the near-dam, deepwater monitoring site during 2005.

5.3.2.1.3 Summer Reservoir Stratification and Hypolimnetic Dissolved Oxygen Conditions

Existing summer thermal stratification and hypolimnetic dissolved oxygen conditions were assessed for Garrison Reservoir, based on monitoring results obtained at the near-dam, deepwater ambient monitoring site during the past 5 years (i.e., 2001 through 2005). Temperature and dissolved oxygen depth profiles were constructed from water quality data collected during the months of July, August, and September. A significant temperature-depth gradient did occur in the reservoir in the near-dam, lacustrine area during the summer, with a thermocline becoming established at a depth of about 25 meters (Plate 17). Dissolved oxygen levels exhibited a significant gradient with depth and tended toward a clinograde vertical distribution (Plate 18). During the period of 2001 through 2005, dissolved oxygen concentrations in the lower hypolimnion fell below 5 mg/l as the summer progressed. At the near-dam, ambient monitoring site, 19 dissolved oxygen measurements below 5 mg/l occurred in depth profiles taken over the 5-year period. All of the measurements occurred in the hypolimnion during the late summer. The lowest value recorded at this site was 3.9 mg/l.

The lowest dissolved oxygen value recorded in the hypolimnion during the 3-year period when the intensive water quality survey was conducted at Garrison Reservoir (i.e., 2003 to 2005) was 1.1 mg/l. This value was measured near the reservoir bottom in the Deepwater Bay area (i.e., RM 1445) on August 24, 2005. The Deepwater Bay area is in the transition zone of the reservoir.

5.3.2.1.4 Trophic State

Trophic State Index (TSI) values for Garrison Reservoir were calculated from monitoring data collected during the past 5 years (i.e. 2001 through 2005) at the near-dam, ambient monitoring site. Table 5.4 summaries the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of the reservoir is in a mesotrophic state. It is noted that during the 5-year period 2001 through 2005, the Garrison Project area has been under a period of extended drought, and the drought conditions may have had an influence on the water quality parameters used to calculate the TSI values.

Table 5.4. Summary of Trophic State Index (TSI) values calculated for Garrison Reservoir for the 5-year period 2001 through 2005.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	26	44	44	35	55
TSI(TP)	22	50	48	41	78
TSI(Chl)	17	44	40	40	64
TSI(Avg1)	26	46	46	39	52
TSI(Avg2)	17	47	46	42	53

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

5.3.2.1.5 Water Quality Special Study Report

Additional information on the existing water quality at Garrison is available in the Water Quality Special Study Report, "Water Quality Conditions Monitored at the Corps' Garrison Project in North Dakota during the 3-Year Period 2003 through 2005" (USACE, 2006b). This report presents the results of the intensive water quality survey that was conducted at Garrison.

5.3.2.2 <u>Water Quality Trends (1980 through 2005)</u>

Water quality trends over the period of 1980 through 2005 were determined for Garrison Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site. Plate 19 displays a scatter-plot of the collected data for the four parameters and a linear regression trend line. For the assessment period, it appears that reservoir exhibited slightly increasing concentrations of total phosphorus and slightly decreasing levels of chlorophyll *a*. There was no observed trend in transparency (i.e. Secchi depth). Over the 26-year period, Garrison Reservoir has generally remained in a mesotrophic state with calculated TSI values showing no observable trend (Plate 19).

5.3.3 WATER QUALITY AT THE GARRISON POWER PLANT

5.3.3.1 <u>Statistical Summary and Water Quality Standards Attainment</u>

Plate 20 summarizes the water quality conditions that were monitored on water discharged through Garrison Dam during the 1-year period of October 2004 through September 2005. A review of these results indicated no significant water quality concerns. Three dissolved oxygen measurements

(<0.1%) did not meet the criterion of 5 mg/l. All three of the measurements occurred on October 1, 2004. No dissolved oxygen measurements during the summer of 2005 were below 5 mg/l. This is attributed to the short-term water quality management measures that were implemented at Garrison Dam during the summer of 2005. Although 16% of the water temperature measurements exceeded 15.0°C, none exceeded 19.0°C. These water temperatures are believed supportive of the cold- and cool-water fishery that exists in the Garrison Dam tailwaters.

5.3.3.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Time series plots for temperature and dam discharge were constructed for the period October 2004 through September 2005 based on monitoring of the water discharged through Garrison Dam (Plates 21 – 24). Monitored water temperatures showed seasonal cooling in the October to December period (Plate 21), remained fairly constant through the January to March period with slight warming occurring later in the period (Plate 22), seasonal warming in the April to May period (Plate 23), considerable variability during June to mid-July, and less variability after mid-July (Plates 23 and 24). Once thermal stratification sets up in the reservoir during the summer, thermal monitoring of the water passed through Garrison Dam clearly indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged intake channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Garrison Reservoir year-round, but is only evident in the temperatures monitored at the powerhouse during reservoir thermal stratification during the summer. The marked change in the variability of the monitored temperatures in mid-July is attributed to the installation of plywood barriers on the lower 48 feet of the trash racks in front of penstocks 2 and 3. Plate 25 shows a plot of water temperatures measured at the Garrison power plant during the period of mid-July through September during 2003, 2004, and 2005. It is evident that the installation of the plywood barriers in 2005 raised the temperature of the water passed through Garrison Dam and discharged to the Missouri River downstream. The increase in temperature in 2005 was, on average, about 2°C.

Time series plots for dissolved oxygen and dam discharge were constructed for the period October 2004 through September 2005 based on monitoring of the water discharged through Garrison Dam (Plates 26 – 29). Dissolved oxygen levels exhibited a steady increase during the October to December period (Plate 26); were somewhat variable during January to March period, but generally remained above 10 mg/l (Plate 27); a steady declined through the April to June period (Plate 28); and steadily declined through the first part of July then exhibited diurnal variability, but generally remained above 6 mg/l from mid-July through September (Plate 29). The steady increase in dissolved oxygen levels in the October to December period is attributed to increasing dissolved oxygen solubility as water temperatures steadily declined. The steady decrease in dissolved oxygen levels in the April to June period is attributed to decreasing dissolved oxygen solubility as water temperatures steadily increased. The decline of dissolved oxygen during late June and July is attributed to ongoing degradation of dissolved oxygen levels in the lower hypolimnion as the summer progressed. The generally stable dissolved oxygen levels with daily variability after mid-July is attributed to the implementation of the short-term water quality management measures (i.e., plywood barriers).

Plate 30 shows a plot of dissolved oxygen concentrations measured at the Garrison power plant during the period of mid-July through September during 2003, 2004, and 2005. It is evident that the installation of the plywood barriers in 2005 raised the dissolved oxygen levels of water passed through Garrison Dam and discharged to the Missouri River downstream. The plywood barriers allowed epilimnetic water, higher in dissolved oxygen, to be drawn into the intake and discharged from the dam. Although the short-term water quality management measures were implemented to preserve coldwater habitat in Garrison Reservoir, they also had the probable benefit of preventing dissolved oxygen levels

below the State of North Dakota's water quality standards criterion (i.e., 5 mg/l) from occurring in the Garrison Dam tailwaters during late summer low flow releases (Plate 30).

5.3.4 IMPLEMENTATION OF SHORT-TERM WATER QUALITY MANAGEMENT MEASURES TO PRESERVE COLDWATER HABITAT IN GARRISON RESERVOIR

The most crucial period for the support of coldwater habitat in Garrison Reservoir is when it begins to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion continues to decrease while the expanding epilimnion has not cooled enough to be supportive of coldwater habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and pinching off coldwater habitat from below. This situation will continue to worsen until the epilimnion cools enough to be supportive of coldwater habitat and the reservoir eventually experiences fall turnover. The volume of the hypolimnion (i.e., of coldwater habitat) occurring in Garrison Reservoir during the summer decreases with lower pool levels.

As drought conditions persisted in early 2005, water levels in Garrison Reservoir had fallen to a record low pool elevation of 1805.8 feet-msl on May 12, 2005. At that time it was felt that unless emergency water quality management measures were implemented in 2005 to preserve the coldwater habitat in the reservoir, the recreational sport fishery would likely be adversely impacted. The reduction of coldwater habitat is exacerbated by withdrawals through the Garrison Dam intake structure. Because the invert elevation of the intake portals to the Garrison Dam power tunnels (i.e., penstocks) is 2 feet above the reservoir bottom, water drawn through the penstocks comes largely from the lower depths of the reservoir. Thus, during the summer thermal-stratification period, water is largely drawn from the hypolimnetic volume of Garrison Reservoir. Three short-term water quality management measures were identified for implementation in an effort to preserve the coldwater habitat in the reservoir. These measures, which were implemented at Garrison Dam, included: 1) modification of the dam's intake trash racks, 2) utilization of head gates to restrict the opening to the dam's power tunnels, and 3) modification of the daily flow cycle and minimum flow releases from the dam. The three implemented water quality management measures were targeted at drawing water into the dam from higher elevations within Garrison Reservoir.

5.3.4.1 <u>Modification of the Dam's Intake Trash Racks</u>

The power tunnels at Garrison Dam are screened at the upstream end of the water passage by trash racks. These trash racks prevent large objects from entering the penstocks and causing serious damage to the wicket gates and turbine. Each of the five penstocks has two intake passages for a total of ten intakes. The trash rack for each of the ten intakes consists of seven separate frame sections. The trash rack fits into the trash rack slots at the front of the intake passage piers. A hook for each rack is fixed to the top of the frame. A lifting beam and mobile crane is used to raise and lower each trash rack.

The existing trash racks were modified to raise the elevation where water was withdrawn from Garrison Reservoir. The trash rack modification consisted of installing plywood sheathing on the upstream side of the existing trash rack grates on the passages to penstocks 2 and 3. The plywood sheathing covered the lower 48 feet of the trash racks (i.e., approximately elevation 1672 to 1720 ft-msl) with the exception of a 3-inch slot at the very bottom for passing sediments. The plywood installation was completed on the trash racks to penstock 3 on July 15, 2005 and on the trash racks to penstock 2 on July 20, 2005. Unfortunately, Unit 3 experienced an unscheduled outage on July 30, 2005. Unit 3 was brought back on-line on September 20, 2005. The positive impact of the plywood barrier installation was likely reduced during the period of Unit 3 non-operation, as water was not drawn through the penstock.

5.3.4.2 Utilization of Head Gates to Restrict the Opening to the Dam's Power Tunnels

Each of the intake passages to all five power tunnels have operational head gates that control flow into the tunnels. It was reasoned that lowering one of the two head gates to block a single passage to the power tunnel should increase the velocity of water drawn into the power tunnel, given the total flow through the power tunnel remained the same. Increasing the velocity of the water drawn into the intake could pull water from a higher elevation in Garrison Reservoir and possibly help maintain the reservoir's deeper, colder volume. To implement this measure, the head gate on one of the passages to penstock 1 was lowered on August 18, 2005 and on one of the passages to penstock 4 on September 1, 2005.

5.3.4.3 Modification of Daily Flow Cycle and Maximum and Minimum Flow Releases

Past water quality monitoring at the Garrison Dam powerhouse indicated that the vertical extent of the withdrawal zone in Garrison Reservoir, during summer thermal stratification, was dependent on the discharge rate of the dam. Warmer water high in dissolved oxygen was drawn down from higher elevations in the reservoir under higher discharge rates, and colder water low in dissolved oxygen was drawn from the lower depths of the reservoir under lower discharge rates. The influence of the dam's discharge rate on the reservoir withdrawal zone is believed to be partly attributed to the design of the intake structure and submerged intake channel.

To the extent possible, flow releases from Garrison Dam were modified to try to maximize the water drawn from higher elevations and minimize the water drawn from lower elevations in Garrison Reservoir. The following two flow release modifications were pursued: 1) daily flow releases should be in either a maximum or minimum mode; and 2) minimum flows should be discharged through penstocks 2 and 3, which have the plywood sheathing in place.

5.3.4.4 Potential Preservation of Coldwater Habitat in Garrison Reservoir Due to the Implementation of Short-term Water Quality Management measures

The potential impact of implementing the short-term water quality management measures on preserving the coldwater habitat in Garrison Reservoir during the period July 22, through September 30, 2005 was estimated by comparing the quantity of water meeting optimal coldwater conditions (i.e., ≤ 15°C and ≥ 5 mg/l dissolved oxygen) that was discharged through each of the dam's five penstocks. The water quality conditions monitored in penstocks 2 and 3 were compared to penstocks 4 and 5. The water quality conditions monitored in penstocks 4 and 5 were taken to be the water quality conditions that would have occurred in penstocks 2 and 3 if the plywood barriers were not in place. Most of the water discharged through penstocks 4, and 5 prior to September 1 met optimal coldwater habitat conditions, while almost all the water discharged through penstocks 2 and 3 did not (i.e., water was warmer than 15°C). This resulted in a potential saving of about 379,390 acre-feet of optimal coldwater habitat in Garrison Reservoir over the 60-day period (Plate 31). All of the potential savings of optimal coldwater habitat occurred prior to September 4 (Plate 31). No water meeting optimal coldwater habitat criteria was discharge through Garrison Dam after September 4 based on monitoring of dynamic water quality conditions in the five penstocks. After September 4, dynamic water temperatures in all the penstocks were above 15°C due to the downward expansion of the epilimnion in the reservoir.

5.3.4.5 Performance Assessment Report

A more detailed discussion of the implementation of the short-term water quality management measures and their effects is given in the Performance Assessment Report, "Garrison Cold Water Fishery Performance Assessment" (USACE, 2006c).

5.4 OAHE

5.4.1 BACKGROUND INFORMATION

Oahe Dam is located on the Missouri River at RM 1072.3 in central South Dakota, 6 miles northwest of Pierre, South Dakota. The closing of Oahe Dam in 1958 resulted in the formation of Oahe Reservoir (Lake Oahe). When full, the reservoir is 231 miles long, covers 374,000 acres, and has 2,250 miles of shoreline. Table 5.5 summarizes how the surface area, volume, mean depth, and retention time of Oahe Reservoir vary with pool elevations. Due to ongoing drought conditions, the reservoir at the end of 2005 (i.e., December 2005) was about 34 feet below the pool elevation of 1607.5 ft-msl which is the top of the Carryover Multiple Use Zone. Major inflows to the reservoir are the Missouri and Cheyenne Rivers. Water discharged through Oahe Dam for power production is withdrawn from Oahe Reservoir at elevation 1525 ft-msl, approximately 110 feet above the reservoir bottom.

Oahe is authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. The power plant has seven units that produce an annual average 2.75 million mega-watt hours of electricity, valued in excess of $30 million in revenue. Habitat for one endangered species, interior least tern, and one threatened species, piping plover, occurs within the project area. Oahe Reservoir is used as a water supply by the town of Fort Yates, North Dakota, and the towns of Bear Creek, Blackfoot, Bridger, Cherry Creek, Dupree, Eagle Butte, Faith, Gettysburg, Green Grass, Iron Lightning, Lantry, LaPlante, Mobridge, Promise, Red Elm, Red Schaffold, Swiftbird, Thunder Butte, Wakpala, and White Horse, South Dakota, as well as some individual cabins. The reservoir is an important recreational resource and a major visitor destination in South Dakota.

Table 5.5. Surface area, volume, mean depth, and retention time of Oahe Reservoir at different pool elevations.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1620	374,135	23,136,960	61.8	1.45
1615	350,960	21,323,520	60.8	1.34
1610	325,765	19,630,460	60.3	1.23
1605	300,030	18,068,750	60.2	1.13
1600	281,010	16,618,390	59.1	1.04
1595	260,715	15,265,460	58.6	0.96
1590	245,190	14,002,600	57.1	0.88
1585	229,085	12,816,650	55.9	0.80
1580	213,150	11,711,030	54.9	0.73
1575	196,915	10,686,750	54.3	0.67
1570	182,933	9,737,896	53.2	0.61
1565	168,523	8,859,708	52.6	0.56
1560	155,510	8,049,792	51.8	0.50
1555	141,688	7,308,917	51.6	0.46
1550	133,628	6,622,830	49.6	0.42
1545	124,869	5,976,361	47.9	0.37
1540	116,560	5,373,030	46.1	0.34

Average Annual Inflow (1967 through 2005) = 16.69 Million Acre-Feet

Average Annual Outflow: (1967 through 2005) = 15.95 Million Acre-Feet

* Mean Depth = Volume ÷ Surface Area.

** Retention Time = Volume ÷ Average Annual Outflow.

Note: Exclusive Flood Control Zone (elev. 1620-1617 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1617-1607.5 ft-msl), Carryover Multiple Use Zone (elev. 1607.5-1540 ft-msl), and Permanent Pool Zone (elev. 1540-1415 ft-msl).

The State of South Dakota has designated the following water quality-dependent beneficial uses for Oahe Reservoir in the State's water quality standards: recreation (i.e., immersion and limited-contact), coldwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the reservoir on the State's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the reservoir.

5.4.2 WATER QUALITY IN OAHE RESERVOIR

5.4.2.1 Existing Water Quality Conditions (2001 through 2005)

5.4.2.1.1 Statistical Summary and Water Quality Standards Attainment

Plate 32 summarizes the water quality conditions that were monitored in Oahe Reservoir from May through September during the 5-year period 2001 through 2005. A review of these results indicated possible water quality concerns regarding water temperature, dissolved oxygen, and pH for the support of coldwater permanent fish life propagation. Water temperatures in the epilimnion of the reservoir regularly exceed 18.3°C in the summer, while temperatures in the hypolimnion are less than 18.3°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses and fall below 7.0 mg/l in late summer (i.e., occurred in non-spawning area outside the spawning season for coldwater species). Dissolved oxygen levels rarely fell below 6.0 mg/l in the hypolimnion in the area of the reservoir near Oahe Dam. Low dissolved oxygen conditions occur in the upstream reaches of the hypolimnion first and progress towards the dam. As the summer progresses, conditions of lower dissolved oxygen move up from the reservoir bottom into the lower reaches of the hypolimnion. The upper pH criterion of 8.6 was exceeded by 19% of the 784 pH measurements taken over the 5-year period. The highest pH value measured was 9.3. No measured pH values were below the lower pH criterion of 6.6.

5.4.2.1.2 Phytoplankton Community

Nine individual phytoplankton grab samples were collected from Oahe Reservoir at the near-dam, deepwater ambient monitoring site during 2004 and 2005 (Plate 33). The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in Oahe Reservoir, based on taxa occurrence, were Bacillariophyta > Cyanobacteria/Chlorophyta/Cryptophyta > Pyrrophyta/Chrysophyta > Euglenophyta. The diatoms were generally the most abundant algae throughout the entire sampling period based on percent composition (Plate 33). The Shannon-Weaver genera diversity index calculated for the nine collected phytoplankton samples ranged from 0.96 to 2.39 and averaged 1.50. Dominant phytoplankton species occurring in the nine collected samples included the Bacillariophyta *Fragilaria spp.* (4 occasions), *Asterionella spp.* (4 occasions), *Aulacoseira spp.* (2 occasions), *Stephanodiscus spp.* (2 occasions), *Cyclotella spp.* (1 occasion), *Synedra* spp. (1 occasion), and *Navicila spp*. (1 occasion); Chlorophyta *Chlamydomonas spp.* (1 occasion); Cryptophyta *Rhodomonas spp.* (2 occasions) and *Cryptomonas spp.* (2 occasions); Pyrrophyta *Peridinium spp.* (2 occasions) and *Ceratium spp.* (2 occasions); Cyanobacteria *Anabaena spp*. (2 occasions); and the Golden Algae *Dinobryon spp.* (2 occasions) (Plate 33). No detectable concentrations of the microcystins toxin were monitored at the near-dam, deepwater monitoring site during 2005.

5.4.2.1.3 Summer Reservoir Stratification and Hypolimnetic Dissolved Oxygen Conditions

Existing summer thermal stratification and hypolimnetic dissolved oxygen conditions were assessed for Oahe Reservoir, based on monitoring results obtained at the near-dam, deepwater ambient monitoring site during the past 5 years (i.e., 2001 through 2005). Temperature and dissolved oxygen depth profiles were constructed from water quality data collected during the months of July, August, and September. A significant temperature-depth gradient occurred in the reservoir in the near-dam lacustrine area during the summer, with a thermocline becoming established at a depth of about 20 meters (Plate 34). Dissolved oxygen levels did not exhibit a large gradient with depth and tended toward an orthograde vertical distribution (Plate 35). During the period of 2001 through 2005, dissolved oxygen concentrations in the hypolimnion generally remained at or above 6 mg/l through the summer (Plate 35). At the near-dam, ambient monitoring site, two dissolved oxygen measurements below 6 mg/l occurred at the reservoir bottom from profiles measured on July 30, 2002 and September 14, 2005.

The lowest dissolved oxygen values recorded in the hypolimnion during the 1-year period the intensive water quality survey was conducted at Oahe Reservoir (i.e., 2005) was in the Whitlocks Bay area (i.e., RM1153). A depth-profile measured on August 16, 2005 indicated the lower 5 meters of the water column at the reservoir bottom had dissolved oxygen concentrations below 4.0 mg/l (minimum value measured was 3.4 mg/l). The Whitlocks Bay area is in the transition zone of Oahe Reservoir.

5.4.2.1.4 Trophic State

Trophic State Index (TSI) values for Oahe Reservoir were calculated from monitoring data collected during the past 5 years (i.e. 2001 through 2005) at the near-dam, ambient monitoring site. Table 5.6 summaries the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of the reservoir is in a mesotrophic state. It is noted that during the 5-year period 2001 through 2005, the Oahe area has been under a period of extended drought, and the drought conditions may have had an influence on the water quality parameters used to calculate the TSI values.

Table 5.6. Summary of Trophic State Index (TSI) values calculated for Oahe Reservoir for the 5-year period 2001 through 2005.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	21	40	39	33	52
TSI(TP)	22	49	50	41	71
TSI(Chl)	16	44	40	40	60
TSI(Avg1)	22	44	44	38	54
TSI(Avg2)	15	46	44	40	56

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

5.4.2.2 <u>Water Quality Trends (1980 through 2005)</u>

Water quality trends over the period of 1980 through 2005 were determined for Oahe Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site. Plate 36 displays a scatter-plot of the collected

data for the four parameters and a linear regression trend line. It appears that the reservoir exhibited slightly increasing concentrations of total phosphorus. There was no observed trend in transparency (i.e. Secchi depth) and chlorophyll *a*. Over the 26-year period, Oahe Reservoir has generally remained in a mesotrophic state with calculated TSI values showing no observable trend (Plate 36).

5.4.3 WATER QUALITY AT THE OAHE POWER PLANT

5.4.3.1 Statistical Summary and Water Quality Standards Attainment

Plate 37 summarizes the water quality conditions that were monitored on water discharged through Oahe Dam during the 1-year period of October 2004 through September 2005. A review of these results indicated possible water quality concerns regarding temperature, dissolved oxygen, and pH for the support of coldwater permanent fish life propagation.

Thirty percent of the recorded hourly temperatures of the water passed through Oahe Dam exceeded the State water quality temperature criterion of 18.3°C. The exceedences of the 18.3°C temperature criterion occurred during the summer. During the summer when Oahe Reservoir is thermally stratified, water temperatures in the epilimnion of the reservoir regularly exceed 18.3°C, while temperatures in the hypolimnion are less than 18.3°C. Water discharged through Oahe Dam for power production is withdrawn from Oahe Reservoir at elevation 1525 ft-msl, approximately 110 feet above the reservoir bottom. Thus, water withdrawn from the reservoir in the summer comes largely from the epilimnion, especially when pool elevations are lower due to drought conditions. Because water passed through Oahe Dam during the summer is withdrawn from the epilimnion of the reservoir, the temperature criterion of 18.3°C for the Missouri River and Big Bend Reservoir just downstream of the dam are not being met during the summer when Oahe Reservoir is thermally stratified.

During the period October 2004 through September 2005, 29 and 19% of the recorded dissolved oxygen concentrations of water passed through Oahe Dam were, respectively, below the State water quality criteria of 7.0 and 6.0 mg/l. Generally, dissolved oxygen levels were below 7.0 mg/l from mid July through September, and below 6.0 mg/l during mid-August through September. Seemingly, the lower dissolved oxygen levels may be related to lower oxygen solubility with warmer water, and possible oxygen degradation in the hypolimnion during late summer. However, a quality assurance review of the dissolved oxygen measurements indicates the potential for significant measurement error. The problem may be due to "fouling" of the membrane on the dissolved oxygen probe over time. To address this situation, a "membrane-less" probe to measure dissolved oxygen was installed at all the continuous monitoring stations at the power plants. It is believed this new methodology will significantly reduce measurement error for future evaluation of dissolved oxygen levels monitored at the Oahe power plant.

Forty-three percent of the pH measurements exceeded the State criteria for the protection of coldwater permanent fish life propagation. All of the exceedences were above the pH criterion of 8.6. No recorded pH values exceeded 9.0, and pH is believed to be a minor concern at this time regarding Oahe Reservoir and the Missouri River and Big Bend Reservoir downstream of Oahe Dam.

5.4.3.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Time series plots for temperature and dam discharge (Plates 38 – 41) and dissolved oxygen and dam discharge (Plates 42 – 45) were constructed for the period October 2004 through September 2005 based on monitoring of the water discharged through Oahe Dam. Water temperatures, during the October to December period, showed seasonal cooling (Plate 38), remained fairly constant during the January to March period (Plate 39), seasonal warming in the April to June period (Plate 40), and some variability

during the July to September period (Plate 41). Dissolved oxygen levels exhibited appreciable variability and a quality assurance review of the dissolved oxygen measurements indicates the potential for significant measurement error. The problem is attributed to "fouling" of the membrane on the dissolved oxygen probe over time. To address this situation, a "membrane-less" probe to measure dissolved oxygen was installed at all the continuous monitoring stations at the power plants. It is believed the new dissolved oxygen probe will significantly reduce measurement error for future evaluation of dissolved oxygen levels monitored at the Oahe power plant.

5.5 BIG BEND

5.5.1 BACKGROUND INFORMATION

Big Bend Dam is located in central South Dakota on the Missouri River at RM 987.4, 21 miles northwest of Chamberlain, South Dakota. The closing of Big Bend Dam in 1963 resulted in the formation of Big Bend Reservoir (Lake Sharpe). The reservoir, when full, is 80 miles long, covers 61,000 acres, and has 200 miles of shoreline. Table 5.7 summarizes how the surface area, volume, mean depth, and retention time of Big Bend Reservoir vary with pool elevations. The Big Bend power plant is operated to meet peak power demands for electricity. Generally, weekly flows from Oahe Dam are released at Big Bend Dam, and there is minimal fluctuation in the water level of Big Bend Reservoir. The Annual Flood Control and Multiple Use Zone in the reservoir does not provide for seasonal regulation of flood inflows like the other major upstream Mainstem System projects, but the zone is used for day-to-day and week-to-week power operations. The Corps normally strives to maintain the pool level in the reservoir between elevation 1419 ft-msl and 1421.5 ft-msl. There are no minimum flow requirements below Big Bend Dam, and hourly releases can fluctuate from 0 to 110,000 cfs for peaking power generation. The major inflows to Big Bend Reservoir are the Missouri River and Bad River. Water discharged through Big Bend Dam for power production is withdrawn from the surface of Big Bend Reservoir.

The reservoir and dam are authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. The power plant has eight generating units that produce an annual average 1.01 million mega-watt hours of electricity, valued in excess of $10 million in revenue. Habitat for one endangered species, interior least tern, and one threatened species, piping plover, occurs within the project area. Big Bend Reservoir is used as a water supply by the Cities of Pierre, Fort Pierre, Fort Thompson, and Lower Brule, South Dakota. The reservoir is an important recreational resource.

Pursuant to the Federal CWA, the State of South Dakota has designated the following water quality-dependent beneficial uses for Big Bend Reservoir: recreation (i.e., immersion and limited-contact), coldwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. Big Bend Dam is the demarcation point between coldwater and warmwater use designation on the Missouri River system in South Dakota. Therefore, the designated use of warmwater permanent fish life propagation applies to the Big Bend Dam tailwaters instead of the coldwater permanent fish life propagation use that applies to Big Bend Reservoir. The State of South Dakota has recently removed Big Bend Reservoir from the State's Section 303(d) list of impaired waters. The reservoir was previously listed as impaired due to accumulated sediment from the Bad River watershed. A total maximum daily load (TMDL) was developed and is being implemented to address this concern, resulting in the delisting of Big Bend Reservoir. South Dakota has not issued a fish consumption advisory for the reservoir.

Table 5.7. Surface area, volume, mean depth, and retention time of Big Bend Reservoir at different pool elevations.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1430	70,615	2,259,568	32.0	0.1286
1425	63,808	1,923,508	30.1	0.1095
1420	57,007	1,621,484	28.4	0.0923
1415	50,224	1,353,339	26.9	0.0770
1410	43,146	1,119,548	25.9	0.0637
1405	35,694	923,872	25.9	0.0526
1400	31,842	756,297	23.8	0.0430
1395	27,402	608,587	22.2	0.0346
1390	24,659	479,172	19.4	0.0273
1385	21,779	362,729	16.7	0.0206
1380	18,307	262,285	14.3	0.0149
1375	14,856	179,548	12.1	0.0102
1370	11,747	113,160	9.6	0.0064
1365	8,590	62,333	7.3	0.0035
1360	5,449	27,069	5.0	0.0015
1355	2,021	9,373	4.6	0.0005
1350	836	2,445	2.9	0.0001

Average Annual Inflow (1967 through 2005) = 17.74 Million Acre-Feet.
Average Annual Outflow: (1967 through 2005) = 17.57 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1423-1422 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1422-1420 ft-msl), Carryover Multiple Use Zone (none), and Permanent Pool Zone (elev. 1420-1345 ft-msl).

5.5.2 WATER QUALITY IN BIG BEND RESERVOIR

5.5.2.1 <u>Existing Water Quality Conditions (2001 through 2005)</u>

5.5.2.1.1 Statistical Summary and Water Quality Standards Attainment

Plate 46 summarizes the water quality conditions that were monitored in Big Bend Reservoir from May through September during the 5-year period 2001 through 2005. A review of these results indicated possible water quality concerns regarding water temperature, dissolved oxygen and pH for the support of coldwater permanent fish life propagation. Based on the criteria for the protection of coldwater permanent fish life propagation, 66% of the observations exceeded water temperature criteria, 4 to 19% of the observations did not meet dissolved oxygen criteria, and 14% of the observations exceed pH criteria. It is noted that if Big Bend Reservoir were classified for the protection of warmwater permanent fish propagation instead of coldwater, no observations would have exceeded the water temperature and pH criteria, and only 1% of the observations would not have met the dissolved oxygen criterion of 5 mg/l. Ambient summer water temperatures in Big Bend Reservoir do not appear to be cold enough to support coldwater permanent fish life propagation as defined by State water quality criteria. Consideration should be given to reclassify the reservoir for a warmwater permanent fish life propagation use based on a use attainability assessment of “natural conditions” regarding ambient water temperatures.

5.5.2.1.2 Phytoplankton Community

Eight individual phytoplankton grab samples were collected from Big Bend Reservoir at the near-dam, deepwater ambient monitoring site during 2004 and 2005 (Plate 47). The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in Big Bend Reservoir, based on taxa occurrence, were Bacillariophyta > Cyanobacteria/Chlorophyta > Cryptophyta > Pyrrophyta/Chrysophyta > Euglenophyta. The diatoms were generally the most abundant algae throughout the entire sampling period based on percent composition (Plate 47). The Shannon-Weaver genera diversity index calculated for the eight collected phytoplankton samples ranged from 0.70 to 2.03 and averaged 1.44. Dominant phytoplankton species occurring in the eight collected samples included the Bacillariophyta *Asterionella spp.* (4 occasions), *Fragilaria spp.* (3 occasions), *Stephanodiscus spp.* (2 occasions), *Navicila spp*. (1 occasion), and *Tabellaria spp.* (1 occasion); Cryptophyta *Rhodomonas spp.* (2 occasions) and *Cryptomonas spp.* (1 occasion); Pyrrophyta *Ceratium spp.* (1 occasion); Cyanobacteria *Anabaena spp*. (1 occasion) and *Pseudanabaena spp.* (1 occasion); and the Golden Algae *Dinobryon spp.* (1 occasion) (Plate 47). No detectable concentrations of the microcystins toxin were monitored at the near-dam, deepwater monitoring site during 2005.

5.5.2.1.3 Summer Reservoir Stratification and Hypolimnetic Dissolved Oxygen Conditions

Existing summer thermal stratification and hypolimnetic dissolved oxygen conditions were assessed for Big Bend Reservoir, based on monitoring results obtained at the near-dam, deepwater ambient monitoring site during the past 5 years (i.e., 2001 through 2005). Temperature and dissolved oxygen depth profiles were constructed from water quality data collected during the months of July, August, and September. No significant temperature-depth gradient was indicated in Big Bend Reservoir in the near-dam lacustrine area during the summer (Plate 48). Except for one occasion, dissolved oxygen levels measured in the near-dam lacustrine area of the reservoir did not exhibit a large gradient with depth and tended toward an orthograde vertical distribution (Plate 49). On one occasion (July 13, 2005), dissolved oxygen levels below 5 mg/l were measured within 5 meters of the reservoir bottom.

5.5.2.1.4 Trophic State

Trophic State Index (TSI) values for Big Bend Reservoir were calculated from monitoring data collected during the past 5 years (i.e. 2001 through 2005) at the near-dam, ambient monitoring site. Table 5.8 summaries the TSI values calculated for the reservoir. The TSI values indicate that the near-dam lacustrine area of Big Bend Reservoir is in a mesotrophic state.

5.5.2.2 Water Quality Trends (1980 through 2005)

Water quality trends over the period of 1980 through 2005 were determined for Big Bend Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site. Plate 50 displays a scatter-plot of the collected data for the four parameters and a linear regression trend line. It appears that the reservoir exhibited increasing concentrations of total phosphorus and decreasing levels of chlorophyll *a* and transparency (i.e. Secchi depth). Over the 26-year period, Big Bend Reservoir has generally remained in a mesotrophic state with calculated TSI values showing no observable trend (Plate 50).

Table 5.8. Summary of Trophic State Index (TSI) values calculated for Big Bend Reservoir for the 5-year period 2001 through 2005.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	18	50	51	37	60
TSI(TP)	22	49	48	41	70
TSI(Chl)	14	46	40	40	67
TSI(Avg1)	22	49	50	40	59
TSI(Avg2)	12	47	47	41	57

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

5.5.3 WATER QUALITY AT THE BIG BEND DAM POWER PLANT

5.5.3.1 Statistical Summary and Water Quality Standards Attainment

Plate 51 summarizes the water quality conditions that were monitored on water discharged through Big Bend Dam during the 1-year period of October 2004 through September 2005. The water quality data-logger installed on the "raw water supply" at Big Bend Dam was not operational from July 7 through September 30. The statistics calculated for temperature, dissolved oxygen, pH, and conductivity are based on measurements taken when the monthly water quality samples were collected. A review of these results indicated a possible water quality concern regarding dissolved oxygen. One dissolved oxygen measurement below 5.0 was measured on July 7, 2006, just prior to when the water quality data logger went out of operation. Dissolved oxygen levels during the summer could be a concern and will be further evaluated in 2006, when the water quality data logger is operational.

5.5.3.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Time series plots for temperature and dam discharge (Plates 52 – 55) and dissolved oxygen and dam discharge (Plates 56 – 59) were constructed for the period October 2004 through September 2005 based on monitoring of the water discharged through Big Bend Dam. As noted above, the water quality data-logger installed on the "raw water supply" at Big Bend Dam was not operation from July 7 through September 30. Water temperatures showed seasonal cooling in the October to December period (Plate 52), remained fairly constant through the January to March period (Plate 53), seasonal warming in the April to June period (Plate 54), and some variability during the July to September period (Plate 55). Dissolved oxygen levels exhibited a steady increase during the October to December period (Plate 56), remained fairly stable through the January to March period (Plate 57), and steadily declined through the April to July period (Plates 58 and 59). The steady increase in dissolved oxygen levels in the October to December period is attributed to increasing dissolved oxygen solubility as water temperatures steadily declined. The steady decrease in dissolved oxygen levels in the April to July period is attributed to decreasing dissolved oxygen solubility as water temperatures steadily increased.

5.6 FORT RANDALL

5.6.1 BACKGROUND INFORMATION

Fort Randall Dam is located on the Missouri River at RM 880.0 in southeastern South Dakota, 50 miles southwest of Mitchell, South Dakota. The closing of Fort Randall Dam in 1952 resulted in the

formation of Fort Randall Reservoir (Lake Francis Case). When full, the reservoir is 107 miles long, covers 102,000 acres, and has 540 miles of shoreline. Table 5.9 summarizes how the surface area, volume, mean depth, and retention time of Fort Randall Reservoir vary with pool elevations. As of December 2005, the reservoir was about 8 feet below the pool elevation of 1350 ft-msl which is the top of the Carryover Multiple Use Zone. A "low" pool level is typical for Fort Randall Reservoir at the end of December because this reservoir is drawn down each fall to provide storage space for high winter power releases from Oahe and Big Bend. Major inflows to Fort Randall Reservoir are the Missouri River and White River. Water discharged through Fort Randall Dam for power production is withdrawn from Fort Randall Reservoir at elevation 1229, approximately 2 feet above the reservoir bottom.

Fort Randall was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. The power plant has eight generating units that produce an annual average 1.79 million mega-watt hours of electricity, valued in excess of $19 million in revenue. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occur within the project area. Fort Randall Reservoir is used as a water supply by the communities of Chamberlain, Dante, Geddes, Greenwood, Kimball, Lake Andes, Marty, Oacoma, Platte, Pickstown, Pukkwana, Ravinia, Reliance, Wagner, and White Lake, South Dakota. The reservoir is an important recreational resource and a major visitor destination in South Dakota.

Table 5.9. Surface area, volume, mean depth, and retention time of Fort Randall Reservoir at different pool elevations.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1370	98,438	4,916,698	49.9	0.268
1365	94,801	4,433,011	46.7	0.241
1360	89,808	3,971,266	44.2	0.216
1355	85,453	3,531,526	41.3	0.192
1350	76,747	3,124,368	40.7	0.170
1345	68,588	2,761,139	40.3	0.150
1340	59,783	2,439,591	40.8	0.133
1335	50,547	2,165,606	42.8	0.118
1330	45,845	1,926,136	42.0	0.105
1325	40,277	1,711,773	42.5	0.093
1320	37,911	1,517,486	40.0	0.083
1315	35,000	1,335,568	38.2	0.073
1310	33,632	1,164,645	34.6	0.063
1305	32,119	1,000,024	31.1	0.054
1300	30,297	843,949	27.9	0.046
1295	28,608	696,350	24.3	0.038
1290	26,042	559,475	21.5	0.030

Average Annual Inflow (1967 through 2005) = 18.63 Million Acre-Feet.
Average Annual Outflow: (1967 through 2005) = 18.35 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1375-1365 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1365-1350 ft-msl), Carryover Multiple Use Zone (1350-1320 ft-msl), and Permanent Pool Zone (elev. 1320-1227 ft-msl).

The State of South Dakota has designated the following water quality-dependent beneficial uses for Fort Randall Reservoir in the State's water quality standards: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed Fort Randall Reservoir on the State's Section 303(d) list of impaired waters, and has not issued a fish consumption advisory for the reservoir.

5.6.2 WATER QUALITY IN FORT RANDALL RESERVOIR

5.6.2.1 Existing Water Quality Conditions (2001 through 2005)

5.6.2.1.1 Statistical Summary and Water Quality Standards Attainment

Plate 60 summarizes the water quality conditions that were monitored in Fort Randall Reservoir from May through September during the 5-year period 2001 through 2005. A review of these results indicated no major water quality concerns. The dissolved oxygen measurements that were below the 5.0 and 6.0 mg/l criteria occurred near the reservoir bottom in the hypolimnion during the summer.

5.6.2.1.2 Phytoplankton Community

Eight individual phytoplankton grab samples were collected from Fort Randall Reservoir at the near-dam, deepwater ambient monitoring site during the period 2004 through 2005 (Plate 61). The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in Fort Randall Reservoir, based on taxa occurrence, were Bacillariophyta > Cyanobacteria/Chlorophyta > Cryptophyta > Pyrrophyta/Chrysophyta/Euglenophyta. The diatoms were generally the most abundant algae throughout the entire sampling period based on percent composition (Plate 61). The Shannon-Weaver genera diversity index calculated for the eight collected phytoplankton samples ranged from 0.76 to 1.92 and averaged 1.43. Dominant phytoplankton species occurring in the eight collected samples included the Bacillariophyta *Fragilaria spp.* (4 occasions), *Asterionella spp.* (2 occasions), *Stephanodiscus spp.* (2 occasions), *Cyclotella spp.* (2 occasions), *Synedra* spp. (2 occasions), *Tabelaria spp*. (1 occasion) and *Melosira spp.* (1 occasion); Cryptophyta *Rhodomonas spp.* (3 occasions) and *Cryptomonas spp.* (2 occasions); Pyrrophyta *Ceratium spp.* (1 occasion); and Cyanobacteria *Planktolyngbya spp.* (1 occasion) and *Oscillatoria spp.* (1 occasion) (Plate 61). No detectable concentrations of the microcystins toxin were monitored at the near-dam, deepwater monitoring site during 2005.

5.6.2.1.3 Summer Reservoir Stratification and Hypolimnetic Dissolved Oxygen Conditions

Existing summer thermal stratification and hypolimnetic dissolved oxygen conditions were assessed for Fort Randall Reservoir based on monitoring results obtained at the near-dam, deepwater, ambient monitoring site during the past 5 years (i.e., 2001 through 2005). Temperature and dissolved oxygen depth profiles were constructed from water quality data collected during the months of July, August, and September. A moderate temperature-depth gradient occurred in Fort Randall Reservoir in the near-dam lacustrine area during the summer, with a thermocline becoming established at a depth of about 25 meters (Plate 62). Dissolved oxygen levels exhibited occasional gradients with depth (Plate 63). On four occasions (i.e., August 29, 2001, August 27, 2003, August 3, 2004, and August 17, 2005), hypolimnetic dissolved concentrations fell below 5.0 mg/l.

5.6.2.1.4 Trophic State

Trophic State Index (TSI) values for Fort Randall Reservoir were calculated from monitoring data collected during the past 5 years (i.e. 2001 through 2005) at the near-dam, ambient monitoring site. Table 5.10 summaries the TSI values calculated for Fort Randall Reservoir. The TSI values indicate that the near-dam, lacustrine area of the reservoir is in a mesotrophic state.

Table 5.10. Summary of Trophic State Index (TSI) values calculated for Fort Randall Reservoir for the 5-year period 2001 through 2005.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	20	46	44	35	56
TSI(TP)	22	48	48	41	61
TSI(Chl)	14	43	40	40	75
TSI(Avg1)	22	47	45	40	65
TSI(Avg2)	13	40	43	43	50

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

5.6.2.2 <u>Water Quality Trends (1980 through 2005)</u>

Water quality trends over the period of 1980 through 2005 were determined for Fort Randall Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site. Plate 64 displays a scatter-plot of the collected data for the four parameters and a linear regression trend line. It appears that Fort Randall Reservoir exhibited increasing concentrations of total phosphorus and decreasing levels of transparency (i.e. Secchi depth) and chlorophyll *a*. Over the 26-year period, the reservoir has generally remained in a mesotrophic state with calculated TSI values showing no observable trend (Plate 64).

5.6.3 WATER QUALITY AT THE FORT RANDALL POWER PLANT

5.6.3.1 <u>Statistical Summary and Water Quality Standards Attainment</u>

Plate 65 summarizes the water quality conditions that were monitored on water discharged through Fort Randall Dam during the 1-year period of October 2004 through September 2005. A review of these results indicated a minor water quality concern regarding dissolved oxygen for the support of warmwater permanent fish life propagation. During the period October 2004 through September 2005, 3 and 2% of the recorded dissolved oxygen concentrations of water passed through Fort Randall Dam were, respectively, below the State water quality criteria of 6.0 and 5.0 mg/l. Generally, dissolved oxygen levels were below these criteria during August. Seemingly, the lower dissolved oxygen levels may be related to lower oxygen solubility with warmer water and oxygen degradation in the hypolimnion during late summer.

5.6.3.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Time series plots for temperature and dam discharge were constructed for the period October 2004 through September 2005, based on monitoring of the water discharged through Fort Randall Dam (Plates 66 – 69). Monitored water temperatures showed seasonal cooling in the October to December period (Plate 66), remained fairly constant through the January to March period with slight warming occurring later in the period (Plate 67), warmed seasonally in the April to May period (Plate 68), varied considerably during June through August, and varied less in September (Plates 68 and 69). Once thermal stratification sets up in Fort Randall Reservoir during the summer, thermal monitoring of the water passed through Fort Randall Dam indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., near-bottom withdrawal) and the presence of a submerged intake channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Fort Randall Reservoir year-round, but the extended zone is only evident in the temperatures monitored at the powerhouse during reservoir thermal stratification during the summer.

Time series plots for dissolved oxygen and dam discharge were constructed for the period October 2004 through September 2005, based on monitoring of the water discharged through Fort Randall Dam (Plates 70 – 73). Dissolved oxygen levels exhibited a steady increase during the October to December period (Plate 70); were somewhat variable during January to March period, but generally remained above 10 mg/l (Plate 71); declined steadily through the April to June period (Plate 72); and continued declining through mid-August, and then increased steadily through September (Plate 73). During August, monitored dissolved oxygen levels varied significantly with flow, with minimum levels approaching 3 mg/l (Plate 73). The lower dissolved oxygen levels were monitored during periods of low discharge and are a reflection that, under lower dam discharge rates, water is drawn from the lower hypolimnion of the reservoir where dissolved oxygen concentrations are reduced.

5.7 GAVINS POINT

5.7.1 BACKGROUND INFORMATION

Gavins Point Dam is located on the Missouri River at RM 811.1 on the South Dakota-Nebraska border in southeast South Dakota and northeast Nebraska, 4 miles west of Yankton, South Dakota. The closing of Gavins Point Dam in 1955 resulted in the formation of Gavins Point Reservoir (Lewis and Clark Lake). The reservoir is 25 miles long, covers 31,000 acres, and has 90 miles of shoreline when full. Table 5.11 summarizes how the surface area, volume, mean depth, and retention time of Gavins Point Reservoir vary with pool elevations. Gavins Point Reservoir is normally regulated near 1206.0 ft-msl in the spring and early summer with variations day to day due to rainfall runoff. The reservoir level is then increased to elevation 1207.5 ft-msl following the least tern and piping plover nesting season for reservoir recreation enhancement. Major inflows to Gavins Point Reservoir are the Missouri River and Niobrara River. Water discharged through Gavins Point Dam for power production is withdrawn from the surface of the reservoir.

Gavins Point was authorized for the proposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. The power plant has three generating units that produce an annual average 0.74 million mega-watt hours of electricity, valued in excess of $8 million in revenue. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occur within the project area. Gavins Point Reservoir is used as a water supply by the Cities of Yankton, Bon Homme, Springfield, and Cedar, South Dakota. Gavins Point is an important recreational resource and a major visitor destination in South Dakota and Nebraska.

Table 5.11. Surface area, volume, mean depth, and retention time of Gavins Point Reservoir at different pool elevations.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1210	30,880	469,928	15.2	0.02316
1205	24,296	332,842	13.7	0.01640
1200	19,713	223,547	11.3	0.01102
1195	14,871	137,085	9.2	0.00676
1190	10,276	74,110	7.2	0.00365
1185	5,283	36,442	6.9	0.00180
1180	3,486	15,631	4.5	0.00077
1175	1,133	4,543	4.0	0.00022
1170	451	1,053	2.3	0.00005

Average Annual Inflow (1967 through 2005) = 20.38 Million Acre-Feet.
Average Annual Outflow: (1967 through 2005) = 20.29 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1210-1208 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1208-1204.5 ft-msl), Carryover Multiple Use Zone (none), and Permanent Pool Zone (elev. 1204.5-1160 ft-msl).

Pursuant to the Federal CWA, the State of South Dakota has designated the following water quality-dependent beneficial uses for Gavins Point Reservoir: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of Nebraska has designated the following beneficial uses to Gavins Point Reservoir: primary contact recreation, Class I warmwater aquatic life, drinking water supply, agricultural water supply, industrial water supply, and aesthetics. The uses designated by the States of South Dakota and Nebraska to Gavins Point Reservoir are consistent with each other. Neither of the States of South Dakota or Nebraska has placed Gavins Point Reservoir on the State's Section 303(d) list of impaired waters, or has issued fish consumption advisories for the reservoir.

5.7.2 WATER QUALITY IN GAVINS POINT RESERVOIR

5.7.2.1 <u>Existing Water Quality Conditions (2001 through 2005)</u>

5.7.2.1.1 Statistical Summary and Water Quality Standards Attainment

Plate 74 summarizes the water quality conditions that were monitored in Gavins Point Reservoir from May through September during the 5-year period 2001 through 2005. A review of these results indicated no major water quality concerns. The dissolved oxygen measurements that were below the 5.0 and 6.0 mg/l criteria occurred near the reservoir bottom in the hypolimnion during the summer.

5.7.2.1.2 Phytoplankton Community

Eight individual phytoplankton grab samples were collected from Gavins Point Reservoir at the near-dam, deepwater ambient monitoring site during the period 2004 through 2005 (Plate 75). The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in Gavins Point

Reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta/Cyanobacteria > Cryptophyta > Pyrrophyta > Euglenophyta/Chrysophyta. The diatoms were generally the most abundant algae throughout the entire sampling period, based on percent composition (Plate 75). The Shannon-Weaver genera diversity index calculated for the eight collected phytoplankton samples ranged from 0.68 to 2.28 and averaged 1.52. Dominant phytoplankton species occurring in the eight collected samples included the Bacillariophyta *Fragilaria spp.* (6 occasions), *Aulacoseira spp.* (3 occasions), *Asterionella spp.* (1 occasion), *Stephanodiscus spp.* (1 occasion), and *Cyclotella spp.* (1 occasion); Cryptophyta *Rhodomonas spp.* (4 occasions) and *Cryptomonas spp.* (2 occasions); Pyrrophyta *Ceratium spp.* (1 occasion); and Cyanobacteria *Aphanothece spp.* (1 occasion) and *Aphanocapsa spp.* (1 occasion) (Plate 75). No detectable concentrations of the microcystins toxin were monitored at the near-dam, deepwater monitoring site during 2005.

5.7.2.1.3 Summer Reservoir Stratification and Hypolimnetic Dissolved Oxygen Conditions

The summer thermal stratification and hypolimnetic dissolved oxygen conditions were assessed for Gavins Point Reservoir, based on monitoring results obtained at the near-dam, deepwater ambient monitoring site during the past 5 years (i.e., 2001 through 2005). Temperature and dissolved oxygen depth profiles were constructed from water quality data collected during the months of July, August, and September. A slight temperature-depth gradient appears to periodically form in the reservoir in the near-dam, lacustrine area during the summer (Plate 76). Dissolved oxygen levels measured in the near-dam, lacustrine area of the reservoir regularly exhibit a significant gradient with depth (Plate 77). On several occasions, dissolved oxygen levels less than 5 mg/l were measured below 5 meters of depth, and approached 2 mg/l near the reservoir bottom.

5.7.2.1.4 Trophic State

Trophic State Index (TSI) values for Gavins Point Reservoir were calculated from monitoring data collected during the past 5 years (i.e. 2001 through 2005) at the near-dam, ambient monitoring site. Table 5.12 summarizes the TSI values calculated for Gavins Point Reservoir. The TSI values indicate that the near-dam, lacustrine area of the reservoir is in a eutrophic state.

Table 5.12. Summary of Trophic State Index (TSI) values calculated for Gavins Point Reservoir for the 5-year period 2001 through 2005.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	25	60	62	50	70
TSI(TP)	25	55	57	41	75
TSI(Chl)	18	54	54	40	69
TSI(Avg1)	25	57	57	49	66
TSI(Avg2)	18	57	57	49	66

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

5.7.2.1.5 Bacteria Monitoring at Swimming Beaches on Gavins Point Reservoir

During the 4-year period 2002 through 2005, bacteria samples were collected weekly from May through September at five swimming beaches located on Gavins Point Reservoir. The five swimming beaches where the bacteria samples were collected were: Weigand Recreation Area (Nebraska), Gavins

Point Recreation Area (South Dakota), Lewis and Clark Recreation Area – Midway West and East Beaches (South Dakota), and Yankton Recreation Area (sailing area). Table 5.13 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following bacteria criteria for support of "full-body contact" recreation:

Fecal Coliform:

Bacteria of the fecal coliform group should not exceed a geometric mean of 200/100ml, nor equal or exceed 400/100ml, in more than 10% of the samples. These criteria are based on a minimum of five samples taken within a 30-day period.

E. coli:

E. coli bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria, "full-body contact" recreation was fully supported at the five sampled swimming beaches on Gavins Point Reservoir during the May through September recreational season during the 4-year period of 2002 through 2005.

5.7.2.2 Water Quality Trends (1980 through 2005)

Water quality trends over the period of 1980 through 2005 were determined for Gavins Point Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site. Plate 78 displays a scatter-plot of the collected data for the four parameters and a linear regression trend line. For the assessment period, it appears that Gavins Point Reservoir exhibited increasing concentrations of total phosphorus and decreasing levels of transparency (i.e. Secchi depth) and chlorophyll *a*. Over the 26-year period, the reservoir has generally remained in a eutrophic state with calculated TSI values showing no observable trend (Plate 78).

5.7.3 WATER QUALITY AT THE GAVINS POINT POWER PLANT

5.7.3.1 Statistical Summary and Water Quality Standards Attainment

Plate 79 summarizes the water quality conditions that were monitored on water discharged through Gavins Point Dam during the 1-year period of October 2004 through September 2005. A review of these results indicated no major water quality concerns.

5.7.3.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Time series plots for temperature and dam discharge were constructed for the period October 2004 through September 2005, based on monitoring of the water discharged through Gavins Pont Dam (Plates 80 – 83). Monitored water temperatures showed seasonal cooling in the October to December period (Plate 80), fairly constant values through the January to March period with slight warming occurring later in the period (Plate 81), seasonal warming in the April to June period (Plate 82), and some variability during July through September with cooling occurring in later September (Plate 83). Water temperatures monitored in the Gavins Point powerhouse exhibited no noticeable correlation to dam discharge rates. Since Gavins Point Dam has a surface withdrawal from Gavins Point Reservoir, conditions monitored in the Gavins Point Powerhouse are indicative of near-surface water quality conditions in the reservoir.

Table 5.13. Summary of weekly (May through September) bacteria sampling conducted at five swimming beaches on Gavins Point Reservoir over the 4-year period 2002 through 2005.

	Weigand Recreation Area	**Gavins Point Recreation Area**	**Lewis & Clark Rec. Area Midway West**	**Lewis & Clark Rec. Area Midway East**	**Yankton Recreation Area (Sailing Area)**
Fecal Coliform Bacteria:					
Number of Samples	86	85	86	86	86
Mean	154	65	37	40	38
Median	20	10	8	7	4
Minimum	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	7,500	780	370	400	520
Percent of samples exceeding 400/100ml	3%	5%	0%	1%	1%
• **Geometric Mean**					
Number of Geomeans	70	69	70	71	70
Average	27	18	12	11	8
Median	19	15	8	6	6
Minimum	2	1	1	1	1
Maximum	140	66	69	67	39
***E.Coli* Bacteria:**					
Number of Samples	84	84	85	85	85
Mean	55	38	27	25	29
Median	14	10	4	n.d.	2
Minimum	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	470	450	260	250	340
Percent of samples exceeding 235/100ml	4%	2%	1%	1%	4%
• **Geomean**					
Number of Geomeans	70	69	70	71	70
Average	18	13	9	8	7
Median	11	8	6	4	5
Minimum	2	2	1	1	1
Maximum	68	56	52	46	58

n.d. = Not detected.
Note: Not detected values set to 1 to calculate mean and geometric mean.

Time series plots for dissolved oxygen and dam discharge were constructed for the period October 2004 through September 2005, based on monitoring of the water discharged through Gavins Point Dam (Plates 84 – 87). Dissolved oxygen levels exhibited a steady increase during December (Plate 84); were somewhat variable during the January to March period, but generally remained above 12 mg/l (Plate 85); were somewhat variable and steadily declined through the April to June period (Plate 86); and were somewhat variable during the July to September period, but generally remained above 6 mg/l (Plate 87). As with water temperature, monitored dissolved oxygen concentrations in the Gavins Point powerhouse exhibited no noticeable correlation to dam discharge rates.

5.8 COMPARISON OF MAINSTEM SYSTEM WATER QUALITY CONDITIONS

5.8.1 ATTAINMENT OF STATE WATER QUALITY STANDARDS

The attainment of water quality standards at the Mainstem System Projects based on water quality conditions monitored over the 5-year period 2001 to 2005 is summarized in Table 5.14. Water quality standards attainment was defined as whether the designated beneficial uses in State water quality standards was supported based on the monitored water quality conditions. It is noted that the "official" determination of whether water quality standards are being attained, pursuant to the Federal CWA, is identified by the States pursuant to their Section 305(b) and Section 303(d) assessments (See Table 1.3).

5.8.2 GENERAL WATER QUALITY CONDITIONS IN THE RESERVOIRS

Table 5.15 summarizes general conditions at the Mainstem System reservoirs based on the water quality monitoring conducted over the 5-year period 2001 through 2005. The four largest reservoirs (i.e., Fort Peck, Garrison, Oahe, and Fort Randall) exhibit characteristics typical of temperate zone dimictic lakes. The four reservoirs exhibit thermal stratification in the summer and winter separated by periods of complete mixing during in the spring and fall turnover periods. A large quiescent hypolimnion forms during the summer in the three larger reservoirs (i.e., Fort Peck, Garrison, and Oahe) with a smaller hypolimnion forming in Fort Randall. The formation of a smaller hypolimnion in Fort Randall Reservoir, as compared to the three other reservoirs, is attributed to its lesser maximum depth and volume. Due to its shallower depth, Gavins point Reservoir appears to be polymixic, with period of summer thermal stratification forming and breaking down as climatic factors change. Big Bend Reservoir does not typically exhibit summer thermal stratification due to its shallower depth and high discharge rates that occur through Big Bend Dam. Severe hypolimnetic dissolved oxygen degradation regularly occurs in Garrison and Gavins Point Reservoirs when thermal stratification persists. Moderate hypolimnetic dissolved oxygen degradation occurs in Fort Randall Reservoir, while only minor hypolimnetic dissolved oxygen degradation appears to occur in Fort Peck and Oahe Reservoirs. Water quality conditions of summer discharges from Garrison and Fort Randall Dams are highly correlated to dam discharge rates. This high degree of correlation of summer water quality conditions of discharged water with dam discharge rate is not evident at the other four Mainstem System dams. The high degree of correlation at Garrison and Fort Randall Dams is attributed to each dam having a near-bottom withdrawal from their impounded reservoirs. The vertical extent of the withdrawal zone in these two reservoirs is dependent on the dam discharge rate. The lacustrine areas of the five upper reservoirs all appear to be mesotrophic, with only Gavins Point being in a eutrophic condition. The prevalence of major phytoplankton groups is similar in all six Mainstem System reservoirs, with diatoms being the most prevalent group.

5.8.3 COMPARISON OF THE EXISTING COLDWATER HABITAT CONDITIONS IN FORT PECK, GARRISON, AND OAHE RESERVOIRS

5.8.3.1 <u>Water Temperature</u>

Near-bottom water temperatures measured at a near-dam, deepwater monitoring station in Fort Peck, Garrison, and Oahe Reservoirs during the "summer" period (i.e., May through September) of 2003, 2004, and 2005 were plotted to compare hypolimnetic water temperatures of the three reservoirs (Plate 88). In all 3 years, the near-bottom water temperature measured in Garrison Reservoir started the "summer" period colder and ended the period warmer than the other two reservoirs (Plate 88). The near-bottom temperature of all three reservoirs increased every year over the "summer" period. The relative rates at which the near-bottom water warmed in the three reservoirs remained consistent over the 3 years; Garrison had the highest rate of warming, Oahe had the lowest, and the rate of warming of Fort Peck was in between (Plate 88).

Table 5.14. Summary of water quality standards attainment (i.e., support of designated beneficial uses) based on water quality conditions monitored at the Mainstem System projects. (Note: "Official" water quality standards attainment is defined in State prepared Section 305(b) and Section 303(d) assessments – See Table 1.3.)

	Recreation[1]	**Coldwater Aquatic Life**	**Warmwater Aquatic Life**	**Domestic Water Supply**	**Agricultural Water Supply**	**Industrial Water Supply**
Fort Peck Reservoir	Unknown	Not Assigned[2]	Full Support	Full Support	Full Support	Full Support
Fort Peck Dam Tailwaters	Unknown	Full Support	Full Support	Full Support	Full Support	Full Support
Garrison Reservoir	Unknown	Threatened[3]	Full Support	Full Support	Full Support	Full Support
Garrison Dam Tailwaters	Unknown	Threatened[4]	Threatened[4]	Full Support	Full Support	Full Support
Oahe Reservoir	Unknown	Full Support	Full Support	Full Support	Full Support	Full Support
Oahe Dam Tailwaters	Unknown	Not Supported[5]	Full Support	Full Support	Full Support	Full Support
Big Bend Reservoir	Unknown	Not Supported[6]	Full Support	Full Support	Full Support	Full Support
Big Bend Dam Tailwaters	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support
Fort Randall Reservoir	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support
Fort Randall Dam Tailwaters	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support
Gavins Point Reservoir	Full Support	Not Assigned	Full Support	Full Support	Full Support	Full Support
Gavins Point Dam Tailwaters	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support

(1) Water quality standards attainment for recreation is based on assessment of collected bacteria data.

(2) The State of Montana has not assigned a coldwater aquatic life use to Fort Peck Reservoir. A coldwater fishery and associated aquatic life do exist in Fort Peck Reservoir and monitored water quality conditions indicate that it is currently fully supported.

(3) Coldwater aquatic life in Garrison Reservoir is currently threatened by warm water temperatures and low dissolved oxygen levels occurring in the hypolimnion during the late summer when reservoir pool levels fall below elevation 1825 ft-msl.

(4) Aquatic life uses in the Garrison Dam tailwaters may be threatened by low dissolved oxygen levels during late summer. Water discharged from Garrison Dam is drawn from the bottom of Garrison Reservoir. The reservoir thermally stratifies during the summer and the lower depths of the hypolimnion experience dissolved oxygen degradation as the summer progresses.

(5) Oahe Reservoir does thermal stratify in the summer and coldwater aquatic life is supported in the reservoir's hypolimnion. However, the power tunnel portals at Oahe Dam are located about 110 feet above the bottom of the reservoir and dam discharges during the summer commonly draw warmer water from the metalimnion and epilimnion – especially when pool elevations are low. Thus, water temperatures in the Oahe Dam tailwaters are not supportive of coldwater aquatic life during the mid to late summer.

(6) Big Bend Reservoir generally does not exhibit sharp thermal stratification in the summer and, therefore, a coldwater hypolimnion does not usually form. The lack of significant summer thermal stratification at the reservoir is attributed to its relative shallowness and the high discharges released through Big Bend Dam associated with its operation to meet peak power demands. Due to the lack of significant summer thermal stratification, ambient water temperatures in Big Bend Reservoir are not cold enough to support coldwater permanent fish life propagation as defined by State water quality criteria. Consideration should be given to reclassify Big Bend Reservoir for a warmwater permanent fish life propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperature.

Table 5.15. Summary of general water quality conditions monitored at the Mainstem System reservoirs over the 5-year period 2001 through 2005.

	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
Maximum reservoir depth near the dam when pool elevation is a top of Carryover Multiple Use Zone.	204 feet	168 feet	193 feet	75 feet	123 feet	48 feet
Extent of hypolimnion formed during summer thermal stratification period	Large (Plate 3)	Large (Plate 17)	Large (Plate 34)	None (Plate 48)	Small (Plate 62)	Very Small (Plate 76)
Extent of dissolved oxygen degradation in the hypolimnion just prior to "fall turnover" of the reservoir	Minor (Plate 4)	Severe (Plate 18)	Minor (Plate 34)	None (Plate 49)	Moderate (Plate 63)	Severe (Plate 77)
Correlation of dam discharge water quality conditions to dam discharge rates during the summer	Low (Plate 10)	High (Plate 24)	Low (Plate 41)	Low (Plate 54)	High (Plate 69)	Low (Plate 83)
Lake trophic status[(1)]	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Eutrophic
Average TSI score[(2)]	44	46	44	49	47	57
Prevalence of sampled phytoplankton groups[(3)] (Note: 1 most prevalent and 7 least prevalent. Groups with same number had similar prevalence.)	1)Bacillariophyta 2)Chlorophyta 2)Cyanobacteria 4)Cryptophyta 4)Pyrrophyta 6)Chrysophyta	1)Bacillariophyta 2)Chlorophyta 2)Cryptophyta 2)Cyanobacteria 5)Pyrrophyta 5)Chrysophyta	1)Bacillariophyta 2)Chlorophyta 2)Cryptophyta 2)Cyanobacteria 5)Chrysophyta 5)Pyrrophyta 7)Euglenophyta	1)Bacillariophyta 2)Chlorophyta 2)Cyanobacteria 4)Cryptophyta 5)Chrysophyta 5)Pyrrophyta 7)Euglenophyta	1)Bacillariophyta 2)Chlorophyta 2)Cyanobacteria 4)Cryptophyta 5)Chrysophyta 5)Euglenophyta 5)Pyrrophyta	1)Bacillariophyta 2)Chlorophyta 2)Cyanobacteria 4)Cryptophyta 5)Pyrrophyta 6)Chrysophyta 6)Euglenophyta

(1) Based on near-dam water quality conditions in the reservoir.
(2) TSI = Trophic State Index (see text for explanation).
(3) Based on phytoplankton samples collected near the dam of each reservoir.

Water temperature-depth profiles measured at the near-dam, deepwater locations at the three reservoirs were used to determine the depth at which water temperatures of 15°C or less occurred. Plate 89 shows a plot of the 15°C water temperature isopleths for Fort Peck, Garrison, and Oahe Reservoirs for 2003, 2004, and 2005. All three reservoirs exhibited surface water temperatures at or below 15°C on around June 1 in each of the 3 years (Plate 89). After June 1 of each year, the 15°C isopleth in all three reservoirs generally moved downward (i.e., 15°C water temperature occurred at a greater depth) through the "summer" period until fall turnover of the reservoirs occurred (Plate 89). The rate of decline of the 15°C isopleth was greatest for Garrison Reservoir for all 3 years (Plate 89). This resulted in Garrison Reservoir having the greatest depth to water having a temperature of 15°C or less in late-summer/early-fall just prior to fall turnover of the reservoirs.

The rate of hypolimnetic warming of the three reservoirs may be related to the depth of water withdrawal from the reservoir. Garrison Reservoir has the deepest level of withdrawal (i.e., 2 feet above the reservoir bottom) and had the highest rate of warming. Oahe Reservoir has the shallowest level of withdrawal (i.e., 110 feet above the reservoir bottom) and had the lowest rate of warming. Fort Peck Reservoir has an intermediary level of withdrawal (i.e., 65 feet above the reservoir bottom) and had an intermediate rate of warming. The near-bottom withdrawal of water from Garrison Reservoir undoubtedly causes mixing within the hypolimnion as water is discharged through the dam and evacuated from lower levels of the hypolimnion. This mixing induces the transfer of heat within the reservoir's hypolimnion and into it from the metalimnion. The elevation of water withdrawal from Oahe Reservoir is generally at or above the thermocline, especially during low pool levels, and extensive mixing and warming of the hypolimnion is not induced. Water withdrawn from Fort Peck Reservoir typically is from the upper depths of the hypolimnion, and some withdrawal induced mixing and warming of the hypolimnion may take place.

5.8.3.2 Dissolved Oxygen

As was done for water temperature, near-bottom dissolved oxygen concentrations measured at the near-dam, deepwater monitoring sites in Fort Peck, Garrison, and Oahe Reservoirs during the "summer" period of 2003, 2004, and 2005 were plotted to compare the hypolimnetic dissolved oxygen conditions of the three reservoirs (Plate 90). For all three years, the near-bottom dissolved oxygen concentrations measured in Garrison Reservoir ended the summer period with lower dissolved oxygen levels than the other two reservoirs (Plate 90). The hypolimnetic dissolved oxygen levels of all three reservoirs decreased every year over the summer period. The relative rates of dissolved oxygen degradation in the near-bottom water of the three reservoirs over the summer periods evaluated were somewhat consistent. Garrison Reservoir appeared to have the highest rate of dissolved oxygen degradation (Plate 90). The hypolimnetic dissolved oxygen degradation rates in Fort Peck and Oahe Reservoirs were similar, except for 2003 were the degradation rate in Fort Peck appeared higher (Plate 90).

For this review, a cursory evaluation of the degradation of hypolimnetic dissolved oxygen in Fort Peck, Garrison, and Oahe Reservoirs considered two possible factors: 1) decomposition of allochthonous and autochthonous organic matter, and 2) transport of oxygen demanding materials and water with low dissolved oxygen concentrations via interflows through the hypolimnion.

5.8.3.2.1 Allochthonous and Autochthonous Organic Matter Loadings

Potential allochthonous and autochthonous organic matter loadings to, Fort Peck, Garrison, and Oahe Reservoirs where evaluated by comparing 2005 monitoring data. The data evaluated were total organic carbon, total phosphorus, and total Kjeldahl nitrogen concentrations and calculated Trophic State Index (TSI) values. The data were from locations that represented the Missouri River inflows and the

riverine, transition, and lacustrine zones of each reservoir. These data are summarized in Table 5.16. At a cursory level, the data indicate no appreciable difference in the potential allochthonous and autochthonous organic matter loadings to each of the three reservoirs (Table 5.16).

Table 5.16. Summary of allochthonous and autochthonous potential nutrient loading indicators based on monitoring data collected at Fort Peck, Garrison, and Oahe Reservoirs during the period May through September 2005.

Location	Total Organic Carbon Mean (mg/l)	Total Phosphorus Mean (mg/l)	Total Kjeldahl Nitrogen Mean (mg/l)	Mean Trophic State Index
Fort Peck:				
Missouri River Inflow	2.7	0.23	0.6	-----
Riverine Zone	2.7	0.10	0.3	52
Transition Zone	2.4	0.04	0.3	47
Lacustrine Zone	2.5	0.05	0.2	45
Garrison:				
Missouri River Inflow	3.2	0.34	0.6	-----
Riverine Zone	3.3	0.06	0.3	58
Transition Zone	3.4	0.04	0.3	52
Lacustrine Zone	2.9	0.03	0.3	47
Oahe:				
Missouri River Inflow	3.4	0.18	0.4	-----
Riverine Zone	3.4	0.06	0.4	58
Transition Zone	3.3	0.06	0.4	51
Lacustrine Zone	3.1	0.06	0.3	47

5.8.3.2.2 Hypolimnetic Mixing and Interflows

The reservoir depth at which the portals for the power tunnels are located is quite different for the Fort Peck, Garrison, and Oahe Projects. Garrison has the deepest level of withdrawal with the invert elevation of the intake tunnels being 2 feet above the reservoir bottom. Oahe has the shallowest level of withdrawal with the crest elevation of the intake tunnels being 110 feet above the reservoir bottom. Fort Peck has an intermediary level of withdrawal with the crest elevation of the intake tunnels being 65 feet above the reservoir bottom. The near-bottom withdrawal of water from Garrison Reservoir undoubtedly causes mixing within the hypolimnion as water discharged through the dam is evacuated from lower levels of the hypolimnion. Given the cursory evaluation that organic matter loadings to each of the three reservoirs is not appreciably different (Table 5.16), anecdotal results suggest that the bottom withdrawal from Garrison Reservoir may be playing a role in causing greater hypolimnetic oxygen demands in the reservoir.

5.8.3.3 <u>Occurrence of Cold-Water Habitat</u>

The occurrence of coldwater habitat in Fort Peck, Garrison, and Oahe was compared based on the presence of optimal coldwater habitat conditions (i.e., temperature ≤15°C and dissolved oxygen ≥ 5 mg/l) measured at a near-dam, deepwater monitoring site in each reservoir. Plates 91, 92, and 93 plot the 15°C water temperature and 5 mg/l dissolved oxygen concentration isopleths measured in each reservoir during 2003, 2004, and 2005. The elevation of the intake into the dam (i.e., lower elevation of withdrawal from each reservoir) is shown as the dotted line (Plate 91, 92, and 93). The occurrence of optimal cold-water

habitat in each reservoir is represented by the area between the 15°C and 5 mg/l isopleths. As shown in Plates 91, 92, and 93, the occurrence of optimal coldwater habitat decreased in each reservoir during the summer; however, the decrease that occurred in Garrison Reservoir was greater. There appears to be a greater degradation of dissolved oxygen in Garrison Reservoir than in Fort Peck or Oahe Reservoirs.

5.9 LOWER MISSOURI RIVER – FORT RANDALL DAM TO RULO, NEBRASKA

5.9.1 CHANNEL CHARACTERISTICS AND TRIBUTARIES

5.9.1.1 Missouri River Reach – Fort Randall Dam to Gavins Point Reservoir

The Missouri River downstream from Fort Randall Dam (RM880.0) flows in a southeasterly direction for approximately 44 miles in an unchannelized river to Gavins Point Reservoir. The major tributary in this reach is the Niobrara River which enters the Missouri River from Nebraska at RM843.5. In this reach, the Missouri River meanders in a wide channel with flow restricted to generally one main channel. Only a few side channels and backwaters are present, except at the lower end of the reach in the Gavins point Reservoir delta. The 39-mile reach of the Missouri River from Fort Randall Dam to Running Water, South Dakota has been designated a National Recreational River under the Federal Wild and Scenic Rivers Act. The tailwater area of Fort Randall Dam, from RM 880 to 860, has experienced up to 6 feet of riverbed degradation and channel widening during the 1953 to 1997 time period. The rate of erosion has decreased over this period. Streambank erosion since closure of the dam in 1953 has averaged about 35 acres per year. This compares to a pre-dam rate of 135 acres per year. The Missouri River has coarser bed material above RM 870 than below, indicating some armoring of the channel below the dam. Downstream of the tailwater area, less erosion of the bed and streambank occurs.

5.9.1.2 Missouri River Reach – Gavins Point Dam to Rulo, NE

The Missouri River between Gavins Point Dam (RM 811.1) and Rulo, NE (RM498.0) flows in an east-southeasterly to south-southeasterly direction. Major tributaries to the Missouri River below Gavins Point Dam, moving downstream, include: James River (SD) at RM 800.8, Vermillion River (SD) at RM 772.0, Big Sioux River (SD and IA) at RM 734.0, Floyd River (IA) at RM 731.1, Little Sioux River (IA) at RM 669.2, Platte River (NE) at RM 494.8, and Nishnabotna River (IA) at RM 542.0. Extensive bed degradation has occurred in the upper areas of this Missouri River reach because river sediment is captured above Gavins Point Dam. Another factor is the substantial Missouri River channel shortening that occurred as part of the downstream Missouri River Bank Stabilization and Navigation Project. Gradual armoring of the riverbed has reduced the rate of channel degradation. Since 1965, approximately 10 feet of stage reduction has occurred for a discharge of 30,000 cfs in the Sioux City, IA area. During this period channel degradation of the Missouri River downstream in the Omaha, NE (RM 615.9) area has been non-existent. This reach of the Missouri River can be separated into three distinct sub reaches: the Missouri River National Recreational River, Kensler's Bend, and the Missouri River Navigation Channel reaches.

5.9.1.2.1 Missouri River National Recreation River Reach

The 59-mile reach of the Missouri River downstream of Gavins Point Dam starting at RM 811.0 down to Ponca, NE (RM 752.0) has been designated a National Recreational River under the Federal Wild and Scenic Rivers Act. This reach of the river has not been channelized by construction of dikes and revetments, and has a meandering channel with many chutes, backwater marshes, sandbars, islands, and variable current velocities. Snags and deep pools are also common. Although this portion of the river includes some bank stabilization structures, the river remains fairly wide. Bank erosion rates since the closure of Gavins Point Dam in 1956 have averaged 132 acres per year between Gavins Point Dam

and Ponca, NE, compared to a pre-dam rate of 202 acres per year. The rate of erosion had been declining since 1975 and then dramatically increased during the high flow years of 1995 through 1997.

5.9.1.2.2 Kensler's Bend Reach

The Kensler's Bend reach of the Missouri River extends from Ponca, NE (RM 752.0) to above Sioux City, IA (RM 735.0). The Missouri River banks have been stabilized with dikes and revetments through this reach, but it has not been channelized.

5.9.1.2.3 Missouri River Navigation Channel Reach

The reach of the Missouri River from the end of the Kensler's Bend reach (RM 735.0) to Rulo, NE (RM 498.0) has been modified over its entire length by an intricate system of dikes and revetments designed to provide a continuous navigation channel without the use of locks and dams. This reach is managed by the Corps under the Missouri River Navigation and Bank Stabilization Project. In addition to the primary authorization to maintain a navigation channel (9 ft deep by 300 ft wide) downstream from Sioux City, IA to the mouth of the Missouri River, there are authorizations to stabilize the river's banks.

5.9.2 FLOW REGULATION

Releases from Gavins point Dam follow the same pattern as those from Fort Randall Dam because there is little active storage in Gavins Point Reservoir. Releases from both dams are based on the amount of water in system storage, which governs how much water will be released to meet service demands in the portion of the lower Missouri River from Sioux City, IA to St. Louis, MO. Constraints for flood control, threatened and endangered bird nesting, and fish spawning requirements also are factors governing releases. Releases from Gavins Point Dam generally fall into three categories: navigation, flood evacuation, and nonnavigation releases.

5.9.2.1 <u>System Service Level</u>

To facilitate appropriate application of multipurpose regulation criteria to the Mainstem System, a numeric "service level" has been adopted since the Mainstem System was first filled in 1967. Quantitatively, this service level approximates the water volume necessary to achieve a normal 8-month navigation season with average downstream tributary flow contributions. For "full-service" and "minimum service" levels, the numeric service level values are, 35,000 cfs and 29,000 cfs, respectively. This service level is used for selection of appropriate flow target values at previously established downstream control locations on the Missouri River. There are four flow target locations selected below Gavins Point Dam to assure that the Missouri River has adequate water available for the entire downstream reach to achieve regulation objectives. The four flow target locations and their flow target discharge deviation from service levels are: Sioux City, IA (-4,000 cfs); Omaha, NE (-4,000 cfs); Nebraska City, NE (+2,000 cfs); and Kansas City, MO (+6,000 cfs). A full-service level of 35,0000 cfs results in target discharges of 31,000 cfs at Sioux City, IA and Omaha, NE; 37.000 cfs at Nebraska City, NE; and 41,000 cfs at Kansas City, MO. Similarly, a minimum-service level of 29,000 cfs results in target values of 6,000 cfs less than the full-service levels at the four target locations. The relation of service levels to the volume of water in System storage is as follows:

Date	Water in System Storage (MAF)	Service Level (cfs)
March 15	54.5 or more*	35,000 (full-service)
March 15	31.0 to 49.0*	29,000 (minimum-service)
March 15	31.0 or less	No Service
July 1	57.0 or more*	35,000 (full-service)
July 1	50.5 or less*	29,000 (minimum-service)
* Straight-line interpolation defines intermediate service levels between full and minimum service.		

The length of the navigation season is determined by the volume of water in storage as follows:

Date	System Storage (MAF)	Season Closure Date at Mouth of Missouri River
March 15	Less than 31.0	No season
July 1	51.5 or more*	December 1 (8-month season)
July 1	41.0 to 46.8*	November 1 (7-month season)
July 1	36.5 or less*	October 1 (6-month season)
* Straight-line interpolation defines intermediate closure date between given values.		

5.9.2.2 Historic Flow Releases

In the navigation season, which generally runs from April 1 through December 1, releases from Gavins Point Dam are generally 25,000 to 35,000 cfs. In the winter, releases are in the 10,000 to 20,000 cfs range. In wet years with above-normal upstream inflows, releases are higher to evacuate flood control storage space in upstream reservoirs. Maximum winter releases are generally kept below 24,000 cfs to minimize downstream flooding problems caused by ice jams in the lower river. During the 1987 to 1993 drought, nonnavigation releases were generally in the 8,000 to 9,000 cfs range immediately following the end and preceding the start of the navigation season. During cold weather, releases were increased up to 15,000 cfs, but generally averaged 12,000 cfs over the 3-month winter period from December through February.

5.9.2.3 Flow Releases for Water Quality management

Generally, Mainstem System project release levels necessary to meet downstream water supply purposes exceed the minimum release levels necessary to meet minimum downstream water quality requirements. Tentative flow requirements for satisfactory water quality were first established by the U.S. Public Health Service and presented in the 1951 Missouri Basin Inter-Agency Committee Report on Adequacy of Flows in the Missouri River. These requirements were used in Mainstem System regulation until revisions were made in 1969 by the Federal Water Pollution Control Administration. The Missouri River minimum daily flow requirements for water quality (i.e., dissolved oxygen) that are given below were initially established by the Federal Water Pollution Control Administration in 1969. They were reaffirmed by the Environmental Protection Agency in 1974 after consideration of: 1) the current status of PL 92-500 programs for managing both point and non-point waste sources discharging into the river, and 2) the satisfactory adherence to the dissolved-oxygen concentration of 5.0 mg/l. The minimum daily flow requirements listed below are used for System regulation purposes.

Location	Dec, Jan, Feb	Mar, Apr	May	Jun, Jul, Aug, Sep	Oct, Nov
Sioux City, IA	1,800 cfs	1,370 cfs	1,800 cfs	3,000 cfs	1,350 cfs
Omaha, NE	4,500 cfs	3,375 cfs	4,500 cfs	7,500 cfs	3,375 cfs
Kansas City, MO	5,400 cfs	4,050 cfs	5,400 cfs	9,000 cfs	4,050 cfs

Low flows in the Missouri River downstream from Gavins Point Dam may affect the ability of power plants on this reach to meet National Pollutant Discharge Elimination System (NPDES) permit thermal limits for discharging cooling water back into the Missouri River.

5.9.2.4 Flow Travel Times

For purposes of scheduling releases, approximate open water travel times from Gavins Point Dam are 1.5 days to Sioux City, IA; 3 days to Omaha, NE; 3.5 days to Nebraska City, NE; 5.5 days to Kansas City, MO; and 10 days to the mouth of the Missouri River near St. Louis, MO.

5.9.3 Historic Flow Conditions (1967 to 2005)

Historic flow conditions for the period 1967 through 2005 were determined from Corps and USGS gaging sites along the Missouri River from Gavins Point Dam to Rulo, NE. The gaging sites include: Gavins Point Dam; Omaha, NE; Nebraska City, NE; and Rulo, NE. Box plots showing the distribution of the mean daily flows measured over the 39-year period are shown in Figure 5.1.

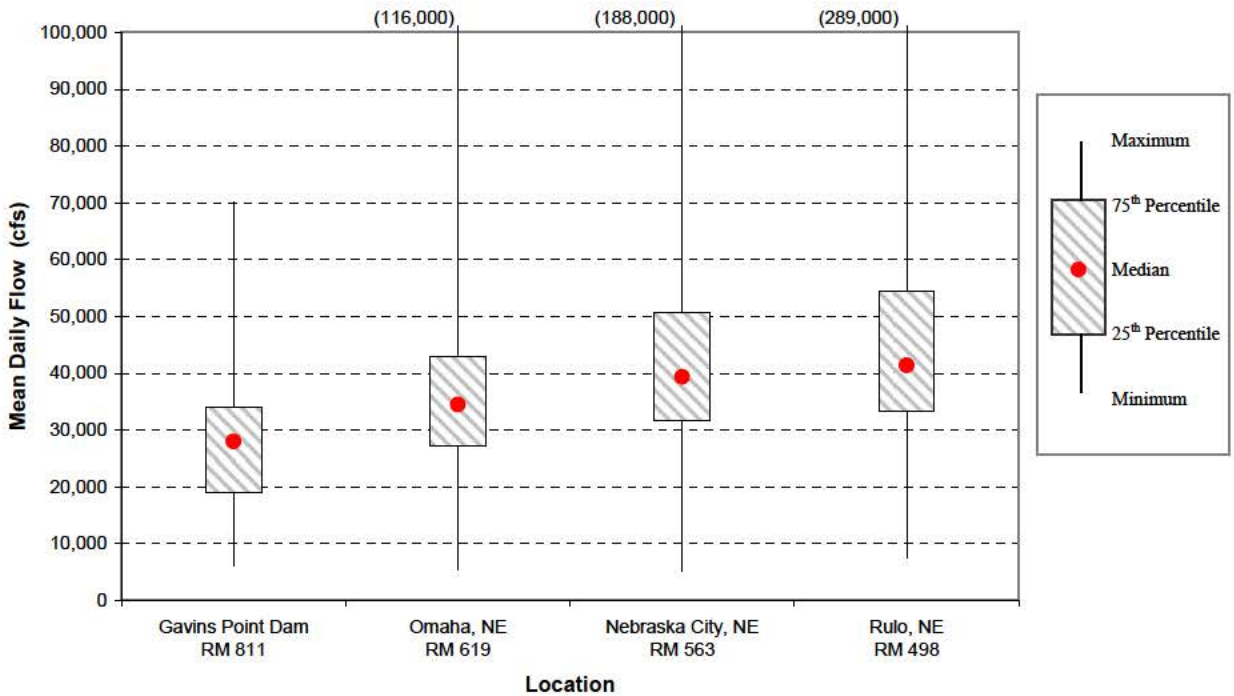

Figure 5.1. Distribution of mean daily flows recorded at gaging sites on the Missouri River at Gavins Point Dam, Omaha, NE, Nebraska City, NE, and Rulo, NE during the 39-year period of 1967 through 2005.

5.9.4 National Recreation River Designation Pursuant to the Federal Wild and Scenic Rivers Act

The 39-mile "natural-channel" reach of the Missouri River from Fort Randall Dam to the headwaters of Gavins Point Reservoir and the 59-mile "natural-channel" reach from Gavins Point Dam to Ponca State Park, Nebraska have been designated as National Recreational Rivers under the Federal Wild and Scenic Rivers Act (WSRA). The National Park Service (NPS) manages the 39-mile reach pursuant to

the WSRA, while the NPS and Corps jointly manage the lower 59-mile reach under the WSRA. The justification that supported that these reaches of the Missouri River be protected as recreational rivers identified their outstanding remarkable recreational, fish and wildlife, aesthetic, historical, and cultural values. Under the WSRA, the U.S. Department of Interior (i.e., NPS) is mandated to administer these reaches in a manner that will protect and enhance these values for the benefit and enjoyment of present and future generations.

5.9.5 STATE DESIGNATIONS AND LISTINGS PURSUANT TO THE FEDERAL CLEAN WATER ACT

Pursuant to the Federal Clean Water Act (CWA), the States of South Dakota, Nebraska, Iowa, and Missouri have designated water quality-dependent beneficial uses, in their State water quality standards, for appropriate reaches of the "free-flowing" Missouri River downstream of Fort Randall Dam. South Dakota has designated the following uses for all of the Missouri River within the state downstream of Fort Randall Dam: primary contact recreation, warmwater fishery, drinking water supply, and industrial water supply. Nebraska has designated the following uses to the entire length of the Missouri River in Nebraska: primary contact recreation, warmwater aquatic life, agricultural water supply, and aesthetics. It has designated the use of drinking water supply to the river below the confluence of the Niobrara River, and industrial water supply to the river below the confluence of the Big Sioux River. Nebraska has also designated the reaches between the Nebraska-South Dakota border and Gavins Point Reservoir and between Gavins Point Dam and Ponca State Park as Outstanding State Resource Waters for "Tier 3" protection under the State's water quality standard's antidegradation policy. Iowa has designated the following uses to all of the Missouri River in the state: primary contact recreation, warmwater fishery, and high quality state resource water. It has also designated the use of drinking water supply to the river in the area of Council Bluffs, Iowa. Missouri has designated the following uses to the river: primary contact recreation, warmwater fishery, drinking water supply, agricultural water supply, and industrial water supply. The States of Nebraska, Iowa, and Missouri have listed the Missouri River on their State's Section 303(d) list of impaired waters. The pollutant/stressors identified are pathogens, siltation, habitat loss, and arsenic. The source of siltation and habitat loss is identified as hydrologic modifications and channelization. The identified sources for the pathogens are municipal point sources, agriculture, and urban runoff.

5.9.6 EXISTING WATER QUALITY CONDITIONS (2001 THROUGH 2005)

5.9.6.1 Statistical Summary and Water Quality Standards Attainment

The Omaha District, in cooperation with the NDEQ, conducted fixed-station water quality monitoring at nine sites along the Missouri River from Fort Randall Dam to Rulo, Nebraska. The location of the nine sites were Fort Randall Dam tailwaters (Station Number FTRRRTW1); near Verdel, NE (Station Number MORRR0851); Gavins Point Dam tailwaters (Station Number GPTRRTW1); near Maskell, NE (Station Number MORRR0774); near Ponca, NE (MORRR0753); at Decatur, NE (Station Number MORRR0691); at Omaha, NE (Station Number MORRR0619); at Nebraska City, NE (Station Number MORRR0563); and at Rulo, NE (Station Number MORRR0498). During the 3-year period of 2003 through 2005 water quality samples were collected monthly from October through March and biweekly from April through September. Plates 94 – 102 summarizes the water quality conditions that were monitored at the nine sites. A review of these results indicated no major water quality concerns.

5.9.6.2 Longitudinal Variation in Water Quality

The distribution of selected parameters measured over the 3-year period of 2003 through 2005 was depicted as box plots at each of the nine monitored locations. The parameters plotted include water temperature, dissolved oxygen, pH, specific conductance, chloride, turbidity, total suspended solids,

chemical oxygen demand, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, and atrazine (Plate 103). For comparison purposes, box plots for the individual parameters measured at each of the nine sites are arranged relative to their respective location in an upstream to downstream order (i.e., FTRRRTW1 = RM880, MORRR0851 = RM880, GPTRRTW1 = RM811, MORRR0774 = RM774, MORRR0753 = RM753, MORR0691 = RM691, MORR0619 = RM619, MORR0563 = RM563, and MORR0498 = RM498). Four longitudinal trends were categorized based on the constructed longitudinal box plots: 1) parameter exhibits no observable longitudinal trend, 2) parameter slightly decreases in a downstream direction, 3) parameter slightly increases in a downstream direction, and 4) parameter greatly increases in a downstream direction. Parameters that exhibited no observable longitudinal trend included pH, conductivity, and total ammonia (Plate 103). Parameters that slightly decreased in a downstream direction included dissolved oxygen (Plate 103). Parameters that slightly increased in a downstream direction included temperature, chlorides, chemical oxygen demand, total organic carbon, total Kjeldahl nitrogen, and atrazine (Plate 103). Parameters that greatly increased in a downstream direction included turbidity, total suspended solids, nitrate-nitrite nitrogen, and total phosphorus (Plate 103).

6 TRIBUTARY PROJECTS

6.1 COLORADO TRIBUTARY PROJECTS

Three District tributary projects are located in Colorado: Bear Creek Reservoir, Chatfield Reservoir, and Cherry Creek Reservoir. All three reservoirs are located in the Denver, Colorado area. Bear Creek Dam is located on Bear Creek in the southwest Denver metropolitan area near Lakewood, Colorado. Chatfield Dam is located on the South Platte River in the south Denver metropolitan area near Littleton, Colorado. Cherry Creek Dam is located on Cherry Creek in the southwest Denver metropolitan area near Aurora, Colorado. The authorized project purposes for Bear Creek and Cherry Creek Reservoirs are: flood control, recreation, and fish and wildlife. The authorized project purposes for Chatfield Reservoir are: flood control, recreation, fish and wildlife, and water supply.

The State of Colorado's water quality standards designate the following beneficial uses to all three tributary project reservoirs: primary contact recreation, domestic water supply, and agriculture. Bear Creek and Chatfield Reservoirs are designated a Class 1 coldwater aquatic life use, and Cherry Creek Reservoir is designated a Class 1 warmwater aquatic life use. Currently, only Chatfield Reservoir is used as a public drinking water supply (i.e., Denver, Englewood, and Littleton, Colorado). Pursuant to Section 303(d) of the CWA, the State of Colorado has placed Bear Creek and Cherry Creek Reservoirs on the State's 303(d) list of impaired waters. Bear Creek Reservoir is listed for impairment to aquatic life due to low dissolved oxygen. Cherry Creek Reservoir is listed for impairment to the uses of aquatic life and primary contact recreation due to elevated chlorophyll *a* levels resulting from high phosphorus loadings to the reservoir.

Local Watershed Management Authorities have been established at all three Colorado Tributary Projects to protect and improve water quality at the reservoirs. Each of these Watershed Authorities has adopted local water quality regulations and water quality management plans to protect and manage water quality at the respective reservoirs. As part of these water quality management plans, the Watershed Authorities are implementing comprehensive water quality monitoring programs. For efficiency purposes, the Corps ceased its water quality monitoring activities at the three Colorado Tributary Projects in 2002, and now defers to the respective Watershed Authorities for assessment of water quality conditions at Bear Creek, Chatfield, and Cherry Creek Reservoirs. Persons interested in water quality conditions at the three Colorado tributary projects can visit the websites maintained by the following groups – Bear Creek Watershed Association (http://www.bearcreekwatershed.org), Chatfield Watershed Authority (http://www.chatfieldwatershed.org), and Cherry Creek Basin Watershed Authority (http://www.cherrycreekbasin.org).

6.2 NEBRASKA TRIBUTARY PROJECTS

Tributary projects in Nebraska occur in two primary watersheds in the southeast area of the State: Salt Creek watershed in the Lincoln area, and Papillion Creek watershed in the Omaha area. Eleven project reservoirs are located in the Salt Creek watershed: Bluestem, Branched Oak, Conestoga, Holmes, Olive Creek, Pawnee, Stagecoach, Twin Lakes (East and West), Wagon Train, and Yankee Hill. Four project reservoirs are located in the Papillion Creek watershed: Ed Zorinsky, Glenn Cunningham, Standing Bear, and Wehrspann. The authorized purposes for the Salt Creek watershed project reservoirs are flood control, recreation, and fish and wildlife management; and the authorized uses for the Papillion Creek watershed project reservoirs are flood control, recreation, fish and wildlife, and water quality. Lake restoration projects have recently been completed on Holmes and Yankee Hill Reservoirs. Holmes

Reservoir has refilled and Yankee Hill Reservoir is in the process of refilling. A lake restoration project is scheduled to begin in 2006 on Glenn Cunningham Reservoir.

The State of Nebraska's water quality standards designates the following beneficial uses to all the Salt Creek and Papillion Creek tributary project reservoirs: recreation, warmwater aquatic life, agricultural water supply, and aesthetics. None of these reservoirs are used as a public drinking water supply. Designated swimming areas are present at Branched Oak, Pawnee, Bluestem, and Wagon Train Reservoirs.

Pursuant to the Federal CWA, the State of Nebraska has listed several of the Salt Creek and Papillion Creek reservoirs as "Category 5" waters on the State's 2004 Section 303(d) list (see Table 1.3). A "Category 5" listing infers that at least one beneficial use is impaired and a TMDL is required. All four of the Papillion Creek reservoirs (i.e., Glenn Cunningham, Standing Bear, Ed Zorinsky, and Wehrspann) are listed as Category 5, as are the following Salt Creek reservoirs, Stagecoach, Bluestem, Conestoga, Olive Creek, East Twin, and West Twin. The beneficial uses impaired include aquatic life and aesthetics. The identified pollutants/stressors include: nutrients, sedimentation, low dissolved oxygen, bacteria, and mercury. The State of Nebraska has issued fish consumption advisories for Ed Zorinsky, Standing Bear, and Wehrspann Reservoirs due to mercury concerns.

6.2.1 PAPILLION CREEK RESERVOIRS

6.2.1.1 <u>Existing Water Quality Conditions (2001 through 2005)</u>

6.2.1.1.1 Statistical Summary and Water Quality Standards Attainment

Plates 104 – 107 respectively, summarize the water quality conditions that were monitored in Ed Zorinsky, Glenn Cunningham, Standing Bear, and Wehrspann Reservoirs from May through September over the 5-year period 2001 through 2005. A review of these results indicated possibly water quality concerns regarding dissolved oxygen, pH, and total ammonia.

A significant number of dissolved oxygen measurements at all four reservoirs were below the 5 mg/l criterion for the protection of warmwater aquatic life. All of the low dissolved oxygen measurements occurred near the bottom of the reservoirs, and appeared to be associated with a slight thermal stratification. Nebraska's Water Quality Standards makes the following provision regarding the application of the State's water quality standards' criteria to lakes:

> *"In lakes and impoundments, or portions thereof, which exhibit natural thermal stratification, all applicable narrative and numerical criteria, with the exception of the numerical criteria for temperature, apply only to the epilimnion."*

This provision seemingly applies to the low dissolved oxygen situation in the four Papillion Creek reservoirs, and the measured dissolved oxygen levels below 5 mg/l are not considered to be a water quality standards nonattainment situation.

A few pH readings at all four reservoirs were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life. In all four reservoirs, the number of pH criterion exceedences was less than 10 percent and are not believed to be a significant concern at this time. It is believed the high pH values may be associated with periods of high algal production and CO_2 uptake during photosynthesis.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in Ed Zorinsky and Wehrspann Reservoirs. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions

when the higher ammonia occurred. Also, the higher ammonia values were generally associated with near-bottom samples and the numeric ammonia criteria may not be applicable if thermal stratification was present. The higher ammonia levels may be associated with the reduction of nitrates as dissolved oxygen is degraded in the hypolimnion during thermal stratification.

6.2.1.1.2 Summer Reservoir Stratification and Dissolved Oxygen Conditions

Profile monitoring indicates that the four Papillion Creek Reservoirs experience enough thermal stratification during the summer to allow anoxic conditions to develop near the reservoir bottom. Due to their relative shallowness, the four reservoirs appear to be polymictic and experience irregular periods of weak thermal stratification throughout the summer. During periods of calm, hot weather, thermal stratification can prevent complete mixing of the reservoirs to the extent that severe degradation of dissolved oxygen occurs near the bottom in deeper areas of the reservoirs.

6.2.1.1.3 Trophic State

Trophic State Index (TSI) values for the four Papillion Creek reservoirs were calculated from monitoring data collected during the past five years (2001 to 2005) at the near-dam, ambient monitoring site. Table 6.1 summarizes the TSI values calculated for Ed Zorinsky, Glenn Cunningham, Standing Bear, and Wehrspann Reservoirs. The TSI values indicate that Ed Zorinsky and Standing Bear are in a eutrophic state, while Glenn Cunningham and Wehrspann are in a hypereutrophic state.

Table 6.1. Mean Trophic State Index (TSI) values calculated for the four Papillion Creek reservoirs for the 5-year period 2001 through 2005.

Reservoir	TSI(SD)	TSI(TP)	TSI(Chl)	TSI(Avg1)	TSI(Avg2)
Ed Zorinsky	61	60	68	63	63
Glenn Cunningham	70	65	72	69	68
Standing Bear	67	59	70	65	65
Wehrspann	68	65	74	69	69

Note: TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

6.2.1.2 <u>Water Quality Trends (1980 through 2005)</u>

Water quality trends over the period 1980 through 2005 were determined for the four Papillion Creek reservoirs for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI. The assessment was based on sampling of water quality conditions in the reservoirs during the months of May through October at the near-dam ambient monitoring site. Plates 108 – 111 display scatter-plots of the collected data for the four parameters and a linear regression trend line. Table 6.2 summarizes the observed trends in the various parameters at the four reservoirs.

Table 6.2. Observable trends in transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., Trophic State Index) based on water quality monitoring conducted at the four Papillion Creek tributary reservoirs over the 26-year period of 1980 through 2005.

Reservoir	Transparency	Total Phosphorus	Chlorophyll *a*	TSI
Ed Zorinsky	Decreasing	None	Increasing	Increasing
Glenn Cunningham	Decreasing	Increasing	None	Increasing
Standing Bear	Decreasing	None	None	None
Wehrspann	Decreasing	None	Increasing	Increasing

6.2.2 SALT CREEK RESERVOIRS

6.2.2.1 <u>Existing Water Quality Conditions (2001 through 2005)</u>

6.2.2.1.1 Statistical Summary and Water Quality Standards Attainment

Plates 112 – 120, respectively, summarize the water quality conditions that were monitored in Bluestem, Branched Oak, Conestoga, East Twin, Olive Creek, Pawnee, Stagecoach, Wagon Train, and West Twin Reservoirs from May through September over the 5-year period 2001 through 2005. Due to their drawdown for renovation, sufficient water quality monitoring data were lacking to allow assessment of Holmes and Yankee Hill Reservoirs. A review of the results for the nine reservoirs assessed indicated possible water quality concerns regarding dissolved oxygen, pH, total ammonia, arsenic, and atrazine.

A significant number of dissolved oxygen measurements (i.e., >10% of the observations) at East Twin, Olive Creek, Pawnee, Stagecoach, Wagon Train, and West Twin Reservoirs were below the 5 mg/l criterion for the protection of warmwater aquatic life. Most of the low dissolved oxygen measurements appeared to occur in the lower depths of the reservoirs. The periods of low dissolved oxygen appear to be associated with two situations: 1) periods of reduced mixing when a slight thermal stratification occurs, and 2) algal respiration during bloom conditions. As previously mentioned, low dissolved oxygen conditions associated with thermal stratification would not be considered a water quality standards nonattainment situation; however, low dissolved oxygen conditions attributed to algal blooms could be.

A significant number of pH measurements (i.e., >10% of the observations) at Conestoga and Olive Creek Reservoirs were above the numeric pH criteria of 9.0 for the protection of warmwater aquatic life. The situation at Olive Creek Reservoir appears to be quite significant with 41 percent of the measurements taken exceeding a pH of 9. Olive Creek Reservoir is a relatively shallow reservoir that experiences algal blooms throughout the summer. It is believed the high pH values at Olive Creek Reservoir are associated with the high algal production and CO_2 uptake during photosynthesis.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in Branched Oak, Conestoga, East Twin, Olive Creek, Pawnee, Wagon Train, and West Twin Reservoirs. A significant exceedence (i.e., >10% of the observations) of the chronic ammonia criterion may have occurred at Conestoga and West Twin Reservoirs. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia occurred. Also, the higher ammonia values may be associated with near-bottom samples and the numeric ammonia criteria may not be applicable if thermal stratification was present. The higher ammonia levels may be associated with the reduction of nitrates as dissolved oxygen is degraded in the hypolimnion during thermal stratification.

A significant number of arsenic measurements (i.e., >10% of the observations) at Olive Creek, Wagon Train, and West Twin Reservoirs exceeded the 16.7 ug/l criterion for the protection of human health and chronic toxicity to aquatic life. The occurrence of arsenic may be related to its natural occurrence in the soils of the region.

A significant number of atrazine measurements (i.e., >10% of the observations) at West Twin Reservoir exceeded the 12 ug/l criterion for the chronic protection of aquatic life. Atrazine is a commonly used herbicide in Nebraska and its presence in the reservoir is attributed to agricultural runoff.

Two reservoirs, Stagecoach and Wagon Train, had a significant number of lead measurements (i.e., >10%) exceeding the chronic criterion for the protection of aquatic life. The lead criterion is hardness dependent, and the criterion cited was based on median hardness values that may not represent conditions when the lead measurements occurred. Also, the number of observations was quite small and the measured value was just slightly above the chronic criterion. This situation is not believed to be a concern at this time.

6.2.2.1.2 Trophic State

Trophic State Index (TSI) values for the nine Salt Creek reservoirs were calculated from monitoring data collected during the past five years (i.e. 2001 to 2005) at the near-dam, ambient monitoring site. Table 6.3 summarizes the TSI values calculated for Bluestem, Branched Oak, Conestoga, East Twin, Olive Creek, Pawnee, Stagecoach, Wagon Train, and West Twin Reservoirs. The TSI values indicate that all the nine assessed Salt Creek reservoirs are in a Hypereutrophic state.

Table 6.3. Mean Trophic State Index (TSI) values calculated for nine Salt Creek reservoirs for the 5-year period 2001 through 2005.

Reservoir	TSI(SD)	TSI(TP)	TSI(Chl)	TSI(Avg1)	TSI(Avg2)
Bluestem	85	72	58	72	72
Branched Oak	72	65	70	69	69
Conestoga	72	68	73	71	71
East Twin	70	63	70	67	68
Olive Creek	79	71	69	73	73
Pawnee	63	65	70	66	66
Stagecoach	78	74	69	74	73
Wagon Train	70	75	68	71	71
West Twin	86	75	73	77	78

Note: TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

6.2.2.2 <u>Water Quality Trends (1980 through 2005)</u>

Water quality trends over the period 1980 through 2005 were determined for eight Salt Creek reservoirs (Bluestem, Branched Oak, Conestoga, Holmes, Olive Creek, Pawnee, Stagecoach, and Wagon Train) for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI. The assessment was

based on sampling of water quality conditions in the reservoirs during the months of May through October at the near-dam monitoring site. Plates 121 – 128 display scatter-plots of the collected data for the four parameters and a linear regression trend line. Table 6.4 summarizes the observed trends in the various parameters at the eight reservoirs.

Table 6.4. Observable trends in transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., Trophic State Index) based on water quality monitoring conducted at eight Salt Creek tributary reservoirs over the 26-year period of 1980 through 2005.

Reservoir	Transparency	Total Phosphorus	Chlorophyll *a*	TSI
Bluestem	Decreasing	Increasing	None	None
Branched Oak	Decreasing	Increasing	Increasing	Increasing
Conestoga	None	Increasing	Increasing	Increasing
Holmes	None	Increasing	None	None
Olive Creek	Increasing	Increasing	Increasing	None
Pawnee	Increasing	Increasing	None	None
Stagecoach	None	Increasing	Decreasing	Increasing
Wagon Train	None	Increasing	None	None

6.3 NORTH DAKOTA TRIBUTARY PROJECTS

Two District tributary reservoir projects are located in North Dakota: Bowman-Haley and Pipestem. Bowman-Haley Reservoir is located in southwest North Dakota along the South Dakota border. The dam is on the North Fork of the Grand River, 6 miles west of Haley, North Dakota. The authorized project purposes of Bowman-Haley Reservoir are flood control, recreation, fish and wildlife, water quality, and water supply. Pipestem Reservoir is located in southeast North Dakota. The dam is located on Pipestem Creek, 3 miles northwest of Jamestown, North Dakota. The authorized project purposes of Pipestem Reservoir are flood control, recreation, fish and wildlife, and water quality.

The State of North Dakota has designated Bowman-Haley and Pipestem Reservoirs as Class 3 lakes in the State's water quality standards. The beneficial uses designated for class I streams are also applicable to all classified lakes in North Dakota. As such, the beneficial uses designated for Bowman-Haley and Pipestem Reservoirs are: primary contact recreation, warmwater fishery, wildlife, and agricultural water supply. Water quality is also to be suitable for municipal or domestic use after appropriate treatment. Neither reservoir is directly used as a municipal or domestic water supply.

6.3.1.1 <u>Existing Water Quality Conditions (2001 through 2005)</u>

6.3.1.1.1 Statistical Summary and Water Quality Standards Attainment

Plates 129 and 130, respectively, summarize the water quality conditions that were monitored in Bowman-Haley and Pipestem Reservoirs from May through September over the 4-year period 2001 through 2004. A review of the results indicated possible water quality concerns regarding dissolved oxygen, pH, and total ammonia.

A significant number of dissolved oxygen measurements (i.e., >10% of the observations) at Pipestem Reservoir were below the 5 mg/l criterion for the protection of warmwater aquatic life. All of the low dissolved oxygen measurements occurred in the lower depths of the reservoirs during periods of

thermal stratification. By mid to late summer the entire hypolimnetic volume of Pipestem Reservoir appears to have dissolved oxygen levels below 5.0 mg/l.

A significant number of pH measurements (i.e., >10% of the observations) at Bowman-Haley Reservoir were above the numeric pH criteria of 9 for the protection of warmwater aquatic life. The maximum pH value measured was 9.2 and the minimum was 7.9.

The chronic ammonia criterion for the protection of warmwater aquatic life was seemingly exceeded in both Bowman-Haley and Pipestem Reservoirs. A significant exceedence (i.e., >10% of the observations) of the chronic ammonia criterion may have occurred at Bowman-Haley Reservoir. Ammonia criteria are pH and temperature dependant, and the criteria cited are based on median values that may or may not represent conditions when the higher ammonia values were measured.

6.3.1.1.2 Trophic State

Trophic State Index (TSI) values for Bowman-Haley and Pipestem Reservoirs were calculated from monitoring data collected during the 4-year period (i.e. 2001 to 2004) at the near-dam, ambient monitoring site. Table 6.5 summarizes the TSI values calculated for the two reservoirs. The TSI values indicate that both reservoirs are in a eutrophic state with Pipestem approaching a hypereutrophic state.

Table 6.5. Mean Trophic State Index (TSI) values calculated for Bowman-Haley and Pipestem Reservoirs for the 4-year period 2001 through 2005.

Reservoir	TSI(SD)	TSI(TP)	TSI(Chl)	TSI(Avg1)	TSI(Avg2)
Bowman Haley	63	62	56	62	61
Pipestem	56	76	63	65	69

Note: TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

6.3.1.2 Water Quality Trends (1980 through 2005)

Water quality trends over the period 1980 through 2005 were determined for Bowman-Haley and Pipestem Reservoirs for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI. The assessment was based on sampling of water quality conditions in the reservoirs during the months of May through October at the near-dam, ambient monitoring site. Plates 131 – 132 display scatter-plots of the collected data for the four parameters and a linear regression trend line. Table 6.6 summarizes the observed trends in the various parameters at the two reservoirs.

Table 6.6. Observable trends in transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., Trophic State Index) based on water quality monitoring conducted at Bowman-Haley and Pipestem Reservoirs over the 26-year period of 1980 through 2005.

Reservoir	Transparency	Total Phosphorus	Chlorophyll *a*	TSI
Bowman-Haley	Increasing	Decreasing	Decreasing	Decreasing
Pipestem	Increasing	Increasing	Decreasing	None

6.4 SOUTH DAKOTA TRIBUTARY PROJECTS

Two District tributary reservoir projects are located in South Dakota: Cold Brook and Cottonwood Springs. Both reservoirs are located in southwest South Dakota in the Hot Springs, South Dakota area. Cold Book Dam is located on Cold Brook Creek approximately 1-mile upstream from its confluence with the Fall River, and 2 miles north of Hot Springs, South Dakota. Cottonwood Springs Dam is located on Cottonwood Springs Creek approximately 5 miles west of Hot Springs South Dakota. The authorized project purposes for both projects are flood control, recreation, fish and wildlife, and water quality.

As identified in the State of South Dakota's water quality standards, the following beneficial uses are designated for both Cold Brook and Cottonwood Springs Reservoirs: recreation (immersion and limited contact), fish and wildlife propagation, stock watering, and domestic water supply. Cold Brook is designated a coldwater permanent fish life propagation use, and Cottonwood Springs is designated a warmwater permanent fish life propagation use.

6.4.1.1 <u>Existing Water Quality Conditions (2001 through 2005)</u>

6.4.1.1.1 Statistical Summary and Water Quality Standards Attainment

Plates 133 and 134, respectively, summarize the water quality conditions that were monitored in Cold Brook and Cottonwood Springs Reservoirs from May through September over the 3-year period 2001 through 2003. A review of the results indicated possibly water quality concerns regarding temperature and dissolved oxygen.

The temperature criterion of 65° F (18.3°C) for the protection of coldwater permanent fish life propagation was exceeded by 75 percent of measurements taken in Cold Brook Reservoir. It is noted that if the reservoir were classified for the protection of coldwater marginal fish life propagation the criterion of 75°F (23.8°C) would have been exceeded 25% of the measurements. The temperature criterion of 80°F (26.6°C) for the protection of warmwater permanent fish life propagation would not have been exceeded at any time. Ambient water temperatures in Cold Brook Reservoir do not appear to be cold enough to support coldwater permanent fish life propagation as defined by State water quality standards criteria. Consideration should be given to reclassify Cold Brook Reservoir for either coldwater marginal fish life propagation or warmwater permanent fish life propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

Dissolved oxygen criteria were exceeded in both Cold Brook and Cottonwood Springs Reservoirs. The lower dissolved oxygen concentrations in both reservoirs occurred in the deeper part of the measured depth profile and were associated with a temperature gradient. The lower dissolved oxygen concentrations in the deeper water of Cold Brook Reservoir may be a concern if a coldwater fishery is to be supported. Water temperatures appear marginal in Cold Brook Reservoir for supporting a coldwater fishery, and the colder water that occurs in the reservoir is in the deeper portions where the lower dissolved oxygen levels occur.

6.4.1.1.2 Trophic State

Trophic State Index (TSI) values for Cold Brook and Cottonwood Springs Reservoirs were calculated from the available data. Table 6.7 summarizes the TSI values calculated for the two reservoirs for the period 2001 through 2003. The TSI values indicate that both reservoirs are in a Mesotrophic state.

Table 6.7. Mean Trophic State Index (TSI) values calculated for Cold Brook and Cottonwood Springs Reservoirs for the 3-year period 2001 through 2003.

Reservoir	TSI(SD)	TSI(TP)	TSI(Chl)	TSI(Avg1)	TSI(Avg2)
Cold Brook	34	51	46	42	45
Cottonwood Springs	34	50	-----	42	-----

Note: TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg1) is the average of TSI values irregardless of the parameters available to calculate the average. TSI(Avg2) is the average of TSI values only when all three parameters were available to calculate the average.

6.4.1.2 Water Quality Trends (1980 through 2005)

Water quality trends over the period 1980 through 2005 were determined for Cold Brook Reservoir for transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI. The assessment was based on sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site. Plate 135 displays scatter-plots of the collected data for the four parameters and a linear regression trend line. Table 6.8 summarizes the observed trends in the various parameters at the reservoir.

Table 6.8. Observable trends in transparency (i.e., Secchi depth), total phosphorus, chlorophyll *a*, and TSI (i.e., Trophic State Index) based on water quality monitoring conducted at Cold Brook Reservoir over the 26-year period of 1980 through 2005.

Reservoir	Transparency	Total Phosphorus	Chlorophyll *a*	TSI
Cold Brook	Increasing	None	Decreasing	None

7 WATER QUALITY MONITORING AND MANAGEMENT ACTIVITIES PLANNED FOR FUTURE YEARS

7.1 WATER QUALITY DATA COLLECTION

A tentative schedule of water quality monitoring targeted for implementation over the 5-year period of 2006 through 2010 is given in Table 7.1. The identified data collection activities are considered the minimum needed to allow for the annual assessment of water quality conditions at District projects, and the preparation of project-specific water quality reports and water quality management objectives for the Missouri River mainstem projects. The actual monitoring activities that are implemented will be dependent upon the availability of future resources.

Table 7.1. Water quality monitoring tentatively planned by the Omaha District's Water Quality Unit for Corps project areas in the District over the next 5 years and the intended data collection approach. Actual monitoring activities implemented will be dependent upon available resources.

Water Bodies to be Monitored	Long-Term Fixed Station Monitoring	Intensive Surveys	Special Studies	Watershed Assessments	Investigative Monitoring
Missouri River and Mainstem Reservoir Project Areas:					
• Fort Peck	X[a]	2004-2006			X[c]
• Garrison	X[a]	Completed			X[c]
• Oahe	X[a]	2005-2007			X[c]
• Big Bend	X[a]	2007-2009			
• Fort Randall	X[a]	2006-2008			X[c]
• Gavins Point	X[a]	2008-2010			X[c]
• Missouri River – Fort Randall Dam to Rulo, Nebraska	X[a]				X[c]
• Lake Yankton (Gavins Point), Lake Pocasse (Oahe), Lake Audubon (Garrison)	2006, 2009				X[c]
Nebraska Tributary Reservoir Project Areas:					
• Bluestem, Branched Oak, Conestoga, East Twin, Ed Zorinsky, Glen Cunningham, Olive Creek, Pawnee, Stagecoach, Standing Bear, Wagon Train, Wehrspann, and West Twin	X[a]			X[b]	X[c]
North Dakota Tributary Reservoir Project Areas:					
• Bowman-Haley and Pipestem	2007, 2010				X[c]
South Dakota Tributary Reservoir Project Areas:					
• Cold Brook and Cottonwood Springs	2005, 2008				X[c]

[a] Planned to be monitored every year.

[b] Watershed Assessments will be implemented, as needed and resources allow, to facilitate development and evaluation of TMDLs in coordination with the Nebraska Department of Environmental Quality.

[c] Investigative Monitoring will be conducted as necessary and appropriate.

7.2 PROJECT-SPECIFIC WATER QUALITY MANAGEMENT PLANNING

Corps guidance for water quality and environmental management at civil works projects (USACE, 1995) identifies the need to develop specific water quality management objectives for each project, and to outline procedures to be implemented to meet those objectives. The identified objectives and procedures are to be included in the project water control plans. The water quality management objectives are to be reviewed and updated as needed, but not less than every 10 years.

The Omaha District's intent is to develop water quality management objectives for each project based on the findings presented in project-specific water quality reports. Therefore, it is important that the project-specific report for a project be updated prior to the development or update of the water quality management objectives for the project. This will ensure that the water quality management objectives for the projects address all of the known surface water quality issues and concerns. Where data are lacking or water quality issues need to be further evaluated, monitoring should be implemented to address these data needs prior to the preparation of the project-specific water quality report. Water quality management objectives will be developed in coordination with project operations staff and, as appropriate, the Northwestern Division's Reservoir Control Center (RCC). The project water quality management objectives will be provided to the District's Engineering and Operation Divisions and RCC for incorporation into Project Water Control Manuals and Master Plans. In line with the priority water quality management issues identified in Table 1.2, the application of the CE-QUAL-W2 hydrodynamic and water quality model and the development of project-specific water quality reports and water quality management objectives will initially be pursued on the Mainstem System projects. The tentative schedule for implementing these water-quality management planning activities on the Mainstem System projects is given in Table 7.2.

Table 7.2. Tentative schedule for water quality management planning activities for the Mainstem System Projects.

Planning Activity	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point	Missouri River*
Ambient water quality monitoring	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
Conduct 3-year intensive water quality survey	2004-06	2003-05	2005-07	2007-09	2006-08	2008-10	**
Prepare Water Quality Special Study Report (Findings of the 3-year intensive water quality survey)	2007	2006	2008	2010	2009	2011	2012
Application of CE-QUAL-W2 Hydrodynamic and Water Quality model	2006-07	2005-06	2007-08	2009-10	2008-09	2010-11	2011-12
Prepare Water Quality Special Study Report (Application of the CE-QUAL-W2 Model)	2007	2006	2008	2010	2009	2011	2012
Prepare Project-Specific Water Quality Report	2008	2007	2009	2011	2010	2012	2013
Develop project-specific water quality management objectives	2008	2007	2009	2011	2010	2012	2013

* Downstream of Gavins Point Dam.
** Water quality data needs may be addressed with ongoing ambient water quality monitoring.

7.3 TOTAL MAXIMUM DAILY LOADS (TMDLS)

The District will participate, as appropriate, as a stakeholder in the development and implementation of TMDLs on water bodies that involve Corps civil works projects.

8 REFERENCES

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9 PLATES

Plate 1. Summary of water quality conditions monitored in Fort Peck Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	21	2210.7	2210.7	2199.4	2222.9	-----	-----	-----
Water Temperature (C)	0.1	728	12.8	11.5	5.6	23.1	27.0	0	0%
Dissolved Oxygen (mg/l)	0.1	728	8.7	8.8	4.2	11.8	≥ 5.0	1	<1%
Dissolved Oxygen (% Sat.)	0.1	728	86.0	89.6	37.6	107.4	-----	-----	-----
Specific Conductance (umho/cm)	1	728	497	495	394	570	-----	-----	-----
pH (S.U.)	0.1	680	8.2	8.2	7.5	8.7	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	592	6.5	3.5	0.4	26.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	544	387	387	298	521	-----	-----	-----
Secchi Depth (in.)	1	19	165	156	72	315	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	163	164	112	184	-----	-----	-----
Ammonia, Total (mg/l)	0.01	43	0.08	0.04	n.d.	0.24	$3.8^{(1,2)}$, $1.8^{(1,3)}$	0	0%
Carbon, Total Organic (mg/l)	0.05	42	2.6	2.5	1.8	3.9	-----	-----	-----
Chemical Oxygen Demand, Total (mg/l)	3	6	5.2	6	3	6	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	499	-----	n.d.	n.d.	4	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	16	-----	n.d.	n.d.	1	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	21	388	370	265	605	-----	-----	-----
Hardness, Total (mg/l)	0.4	19	212	207	199	262	-----	-----	-----
Iron, Dissolved (ug/l)	40	15	-----	n.d.	n.d.	n.d.	-----	-----	-----
Iron, Total (ug/l)	40	19	71	67	n.d.	184	$1{,}000^{(3)}$	0	0%
Kjeldahl N, Total (mg/l)	0.1	51	-----	0.2	n.d.	0.6	-----	-----	-----
Manganese, Dissolved (ug/l)	1	15	-----	n.d.	n.d.	12	-----	-----	-----
Manganese, Total (ug/l)	1	19	-----	4	n.d.	27	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	35	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.01	27	0.04	0.03	n.d.	0.32	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	51	0.05	0.03	n.d.	0.66	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	51	-----	n.d.	n.d.	0.02	-----	-----	-----
Sulfate (mg/l)	0.1	27	117	120	37	130	-----	-----	-----
Suspended Solids, Total (mg/l)	4	51	-----	n.d.	n.d.	8	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	$6^{(4)}$	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	$340^{(2)}$, $150^{(3)}$, $18^{(4)}$	0	0%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	$4^{(4)}$	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	$4.5^{(2)}$, $0.5^{(3)}$, $5^{(4)}$	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	$3{,}272^{(2)}$, $156^{(3)}$, $100^{(4)}$	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	$27.8^{(2)}$, $17.4^{(3)}$, $1300^{(4)}$	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	$206^{(2)}$, $8.0^{(3)}$, $15^{(4)}$	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	$1.7^{(2)}$, $0.91^{(3)}$, $0.05^{(4)}$	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	0.06	$1.7^{(2)}$, $0.91^{(3)}$, $0.05^{(4)}$	1*****	25%*****
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	$868^{(2)}$, $97^{(3)}$, $100^{(4)}$	0	0%
Selenium, Total (ug/l)	4	3	-----	n.d.	n.d.	n.d.	$20^{(2)}$, $5^{(3)}$, $50^{(4)}$	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	14 $2.0^{(2)}$, $100^{(4)}$	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	$223^{1,2)}$, $2{,}000^{(4)}$	0	0%
Alachlor, Total (ug/l)	0.05	13	-----	n.d.	n.d.	n.d.	2	0	0%
Atrazine, Total (ug/l)	0.05	13	-----	n.d.	n.d.	0.6	3	0	0%
Metolachlor, Total (ug/l)	0.05	13	-----	n.d.	n.d.	0.07	100	0	0%
Pesticide Scan (ug/l)***	0.05	3	-----	n.d.	n.d.	n.d.	****	0	0%
Microcystins, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean)..

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.2 and 11.5 respectively.
(2) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
(3) Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
(4) Human health criterion for surface waters.
Note: Montana's WQS criteria for metals are based on total recoverable, most analyzed metal concentrations were dissolved. Listed criteria are given for comparison and were calculated using the median hardness of 207 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

***** One out of four total mercury measurements exceeded the human health criterion.

Plate 2. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division, and dominant taxa present for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site at Fort Peck Reservoir during the period 2004 through 2005.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
May 2004	785,288	1	0.02	0	-----	0	-----	1	0.57	2	0.41	0	-----	0	-----	0.87
Jun 2004	5,099,022	3	0 21	0	-----	0	-----	1	0.65	3	0.13	0	-----	0	-----	1.15
Jul 2004	106,065,880	3	1.00	0	-----	0	-----	1	<0.01	2	<0.01	0	-----	0	-----	0.96
Aug 2004	47,445,368	4	0.93	1	<0.01	0	-----	1	0.05	3	0.02	0	-----	0	-----	1.59
Sep 2004	47,026,614	6	0.66	7	0.10	0	-----	1	0.09	4	0.09	1	0.05	0	-----	2.11
May 2005	515,757,980	10	0.92	1	<0.01	2	0.07	0	-----	0	-----	0	-----	0	-----	1.28
Jun 2005	46,921,234	5	0.90	1	<0.01	0	-----	0	-----	1	<0.01	1	0.09	0	-----	1.61
Jul 2005	156,655,118	4	0.79	1	<0.01	0	-----	2	0.07	5	0.02	2	0.11	0	-----	1.51
Aug 2005	329,301,346	7	0.46	3	<0.01	1	<0.01	1	0.05	6	0.18	2	0.30	0	-----	2.20
Sep 2005	138,703,297	7	0.38	9	0.08	0	-----	1	<0.01	5	0.05	1	0.47	0	-----	1.62
Mean*	**139,376,115**	**5.0**	**0.63**	**2.3**	**0.03**	**0.3**	**0.04**	**0.9**	**0.19**	**3.1**	**0.10**	**0.7**	**0.20**	**0**	**-----**	**1.49**

* Mean percent composition represents the mean when taxa of that division are present.

Date	Division	Dominant Taxa*	Percent of Total Biovolume	Date	Division	Dominant Taxa	Percent of Total Biovolume
May 2004	Cryptophyta	*Rhodomonas minuta*	0.57	May 2005	Bacillariophyta	*Asterionella formossa*	0.52
	Cyanobacteria	*Aphanocapsa spp.*	0.38		Bacillariophyta	*Stephanodiscus spp.*	0.29
June 2004	Cryptophyta	*Rhodomonas minuta*	0.65	June 2005	Bacillariophyta	*Aulacoseira granulata*	0.39
	Bacillariophyta	*Cyclotella spp.*	0.17		Bacillariophyta	*Fragilaria crotonensis*	0.23
					Bacillariophyta	*Synedra delicatissima*	0.16
July 2004	Bacillariophyta	*Asterionella formossa*	0.60	July 2005	Bacillariophyta	*Asterionella formossa*	0.44
	Bacillariophyta	*Fragilaria crotonensis*	0.25		Bacillariophyta	*Fragilaria crotonensis*	0.29
	Bacillariophyta	*Cyclotella spp.*	0.14		Pyrrophyta	*Ceratium hirundinella*	0.11
August 2004	Bacillariophyta	*Fragilaria crotonensis*	0.32	August 2005	Pyrrophyta	*Peridinium spp.*	0.23
	Bacillariophyta	*Aulacoseira islandica*	0.25		Bacillariophyta	*Asterionella formossa*	0.21
	Bacillariophyta	*Synedra spp.*	0.19		Bacillariophyta	*Fragilaria crotonensis*	0.14
	Bacillariophyta	*Cyclotella spp.*	0.16				
September 2004	Bacillariophyta	*Fragilaria crotonensis*	0.34	September 2005	Pyrrophyta	*Peridinium spp.*	0.47
	Bacillariophyta	*Aulacoseira islandica*	0.15		Bacillariophyta	*Stephanodiscus hantzschii*	0.19
					Bacillariophyta	*Fragilaria spp.*	0.16

* Dominant taxa are genera or species (depending on identification level) that comprised more than 10% of the total sample biovolume.

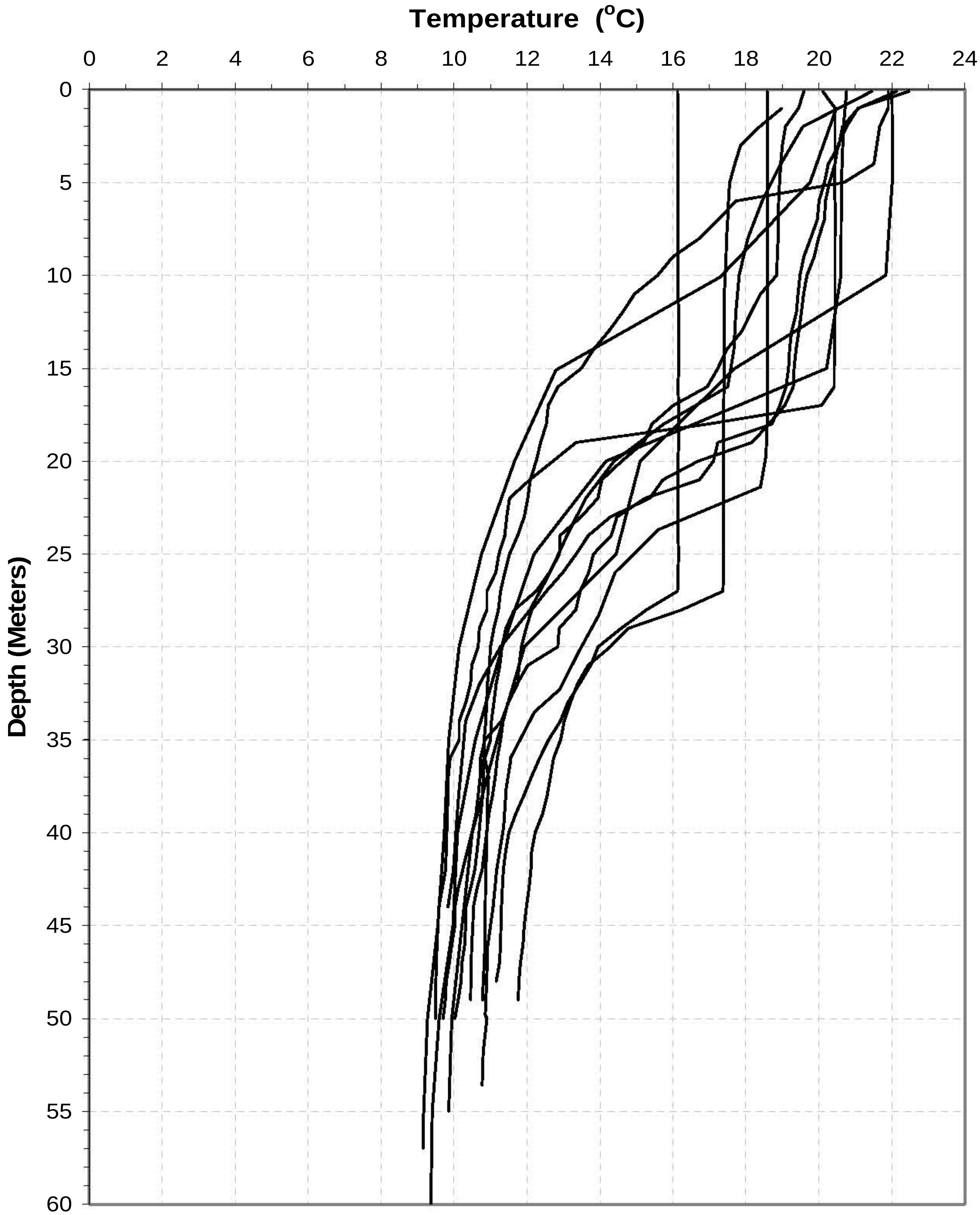


Plate 3. Temperature depth profiles for Fort Peck Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005.

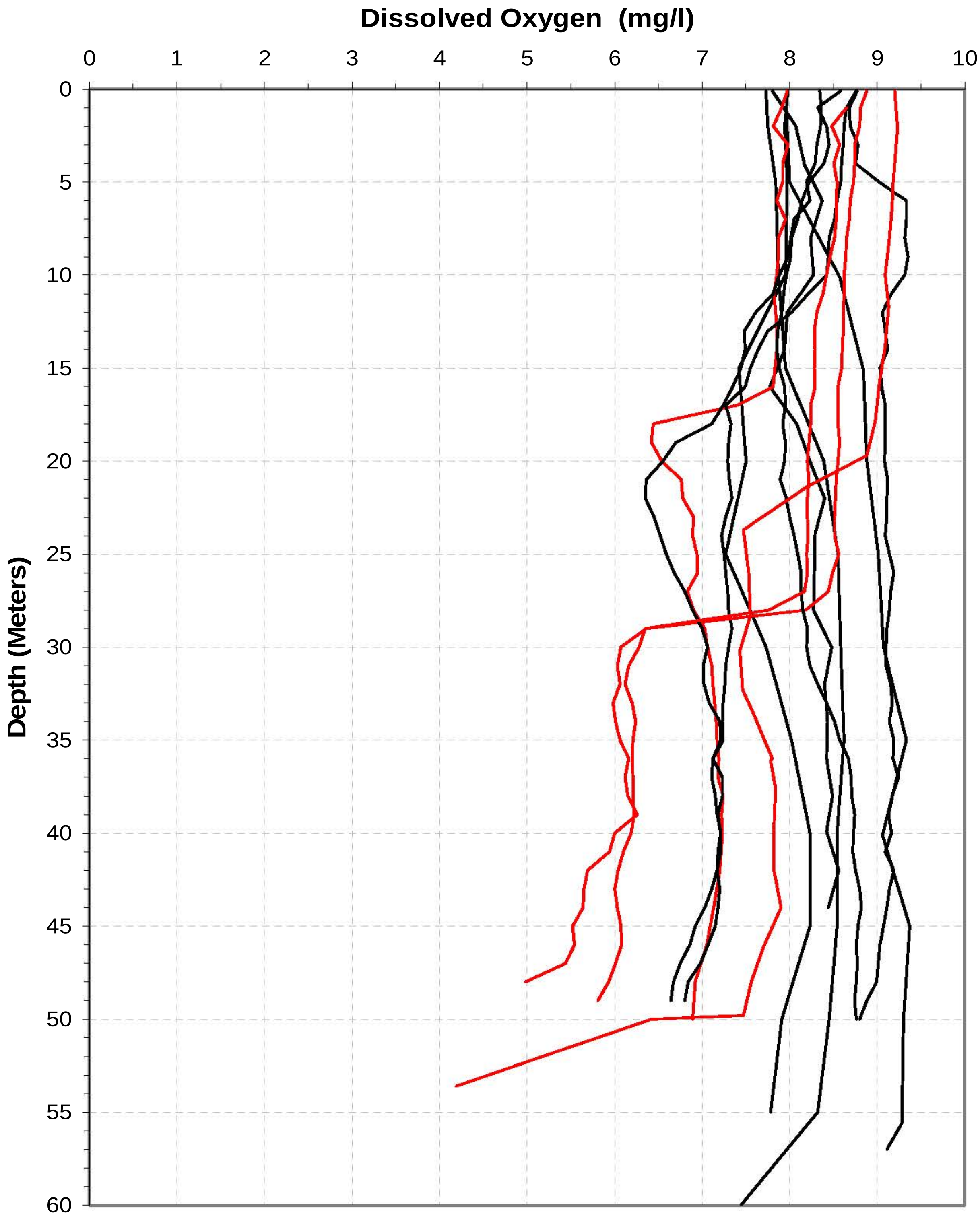


Plate 4. Dissolved oxygen depth profiles for Fort Peck Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005. (Note: Red profiles were measured in the month of September.)

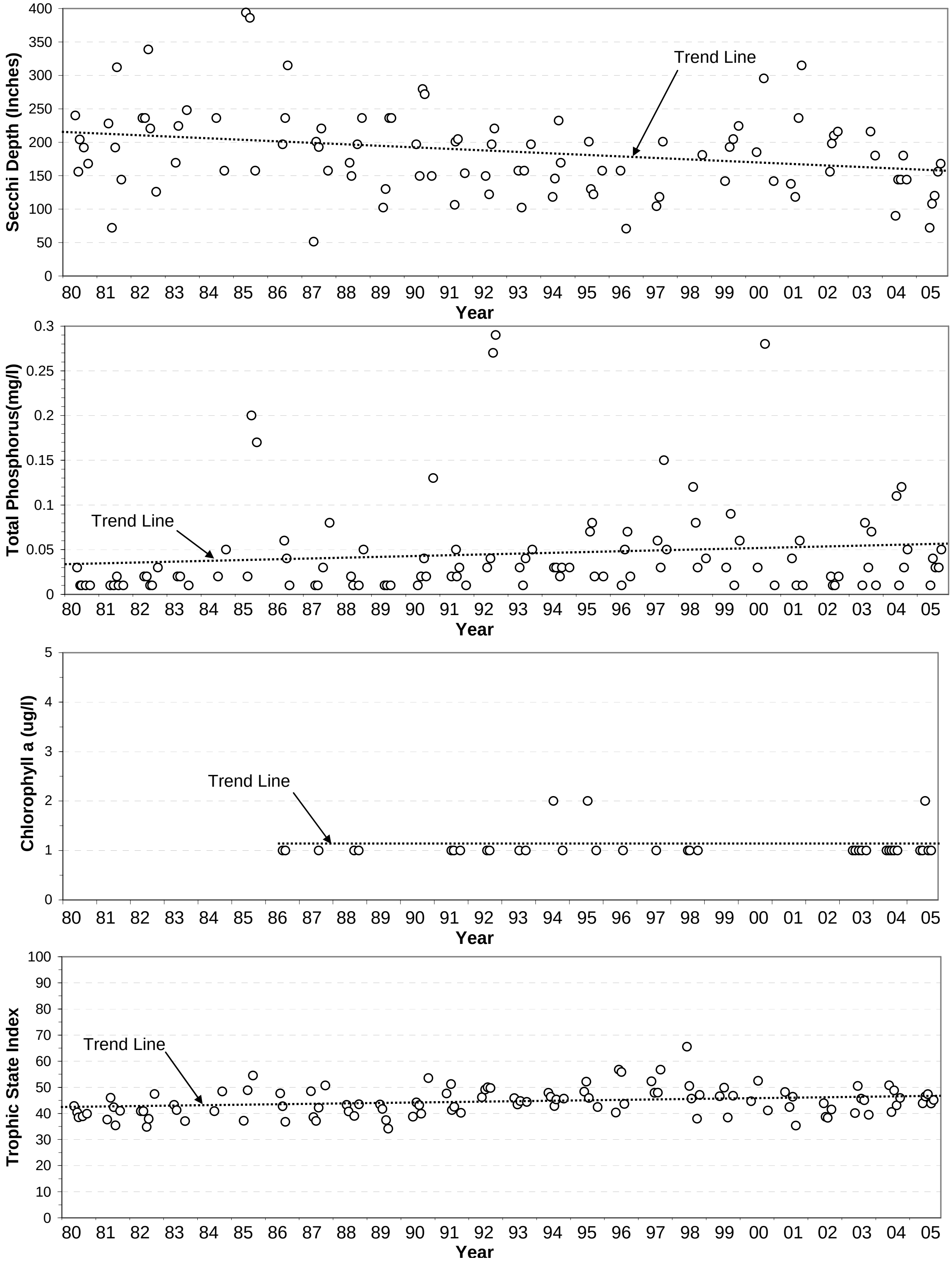


Plate 5. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Fort Peck Reservoir at the near-dam, ambient site over the 26-year period of 1980 to 2005.

Plate 6. Summary of water quality conditions monitored on water discharged through Fort Peck Dam during the 1-year period of October 1, 2004 through September 30, 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Dam Discharge (cfs)	1	8,759	5,433	5,390	2,340	10,880	-----	-----	-----
Water Temperature (C)	0.1	7,543	8.6	8.0	1.9	19.3	19.4	0	0%
Dissolved Oxygen (mg/l)	0.1	7,479	9.4	9.7	5.3	12.9	≥ 8.0 ≥ 5.0	1,932 0	26% 0%
Dissolved Oxygen (% Sat.)	0.1	7,479	85.4	86.3	54.9	107.5	-----	-----	-----
Specific Conductance (umho/cm)	1	7,543	474	516	375	546	-----	-----	-----
pH (S.U.)	0.1	7,543	8.3	8.4	7.7	8.7	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	11	166	167	160	177	-----	-----	-----
Ammonia, Total (mg/l)	0.01	11	0.06	0.04	n.d.	0.18	2.6 (1,2), 1.3 (1,3)	0	0%
Carbon, Total Organic (mg/l)	0.05	11	2.6	2.4	2.2	3.2	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	11	352	349	306	427	-----	-----	-----
Hardness, Total (mg/l)	0.4	2	204	204	200	208	-----	-----	-----
Iron, Dissolved (ug/l)	40	10	-----	n.d.	n.d.	40	-----	-----	-----
Iron, Total (ug/l)	40	11	171	149	n.d.	683	1,000(3)	0	0%
Kjeldahl N, Total (mg/l)	0.1	11	0.5	0.2	0.1	2.2	-----	-----	-----
Manganese, Dissolved (ug/l)	1	10	-----	1	n.d.	3	-----	-----	-----
Manganese, Total (ug/l)	1	11	12	7	3	38	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	11	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.01	5	0.03	0.03	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	11	0.06	0.07	n.d.	0.14	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	11	-----	n.d.	n.d.	n.d.	-----	-----	-----
Sulfate (mg/l)	0.1	11	149	130	120	209	-----	-----	-----
Suspended Solids, Total (mg/l)	4	51	-----	n.d.	n.d.	80	-----	-----	-----
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6(4)	0	0%
Arsenic, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	3	340(2), 150(3), 18(4)	0	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4(4)	0	0%
Cadmium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	4.5(2), 0.5(3), 5(4)	0	0%
Chromium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	3,272(2), 156(3), 100(4)	0	0%
Copper, Dissolved (ug/l)	2	2	-----	2	n.d.	4	27.8(2), 17.4(3), 1300(4)	0	0%
Lead, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	206(2), 8.0(3), 15(4)	0	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.7(2), 0.91(3), 0.05(4)	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	0.06	1.7(2), 0.91(3), 0.05(4)	0	0%
Nickel, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	n.d.	868(2), 97(3), 100(4)	0	0%
Selenium, Total (ug/l)	4	2	-----	n.d.	n.d.	n.d.	20(2), 5(3), 50(4)	0	0%
Silver, Dissolved (ug/l)	1	2	-----	n.d.	n.d.	n.d.	14 2.0(2), 100(4)	0	0%
Zinc, Dissolved (ug/l)	3	2	-----	8	8	8	223(1,2), 2,000(4)	0	0%
Pesticide Scan (ug/l)***	0.05	3	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean)..

** (1)Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.4 and 8.0 respectively.
(2) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
(3) Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
(4)Human health criterion for surface waters.
Note: Montana's WQS criteria for metals are based on total recoverable, most analyzed metal concentrations were dissolved. Listed criteria are given for comparison and were calculated using the median hardness of 204 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

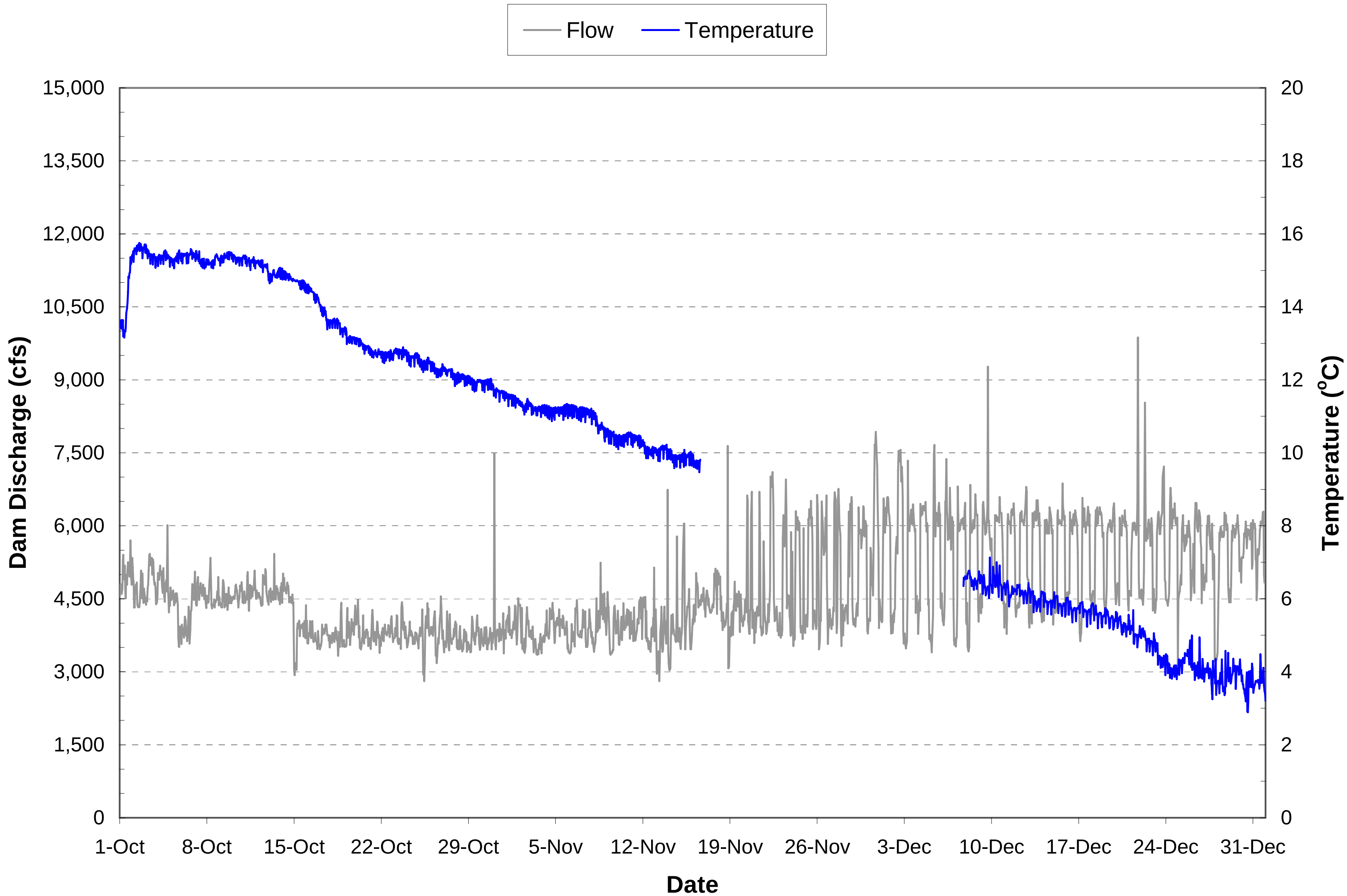


Plate 7. Hourly discharge and water temperature monitored at the Fort Peck power plant on water discharged through the dam during the period October through December 2004. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

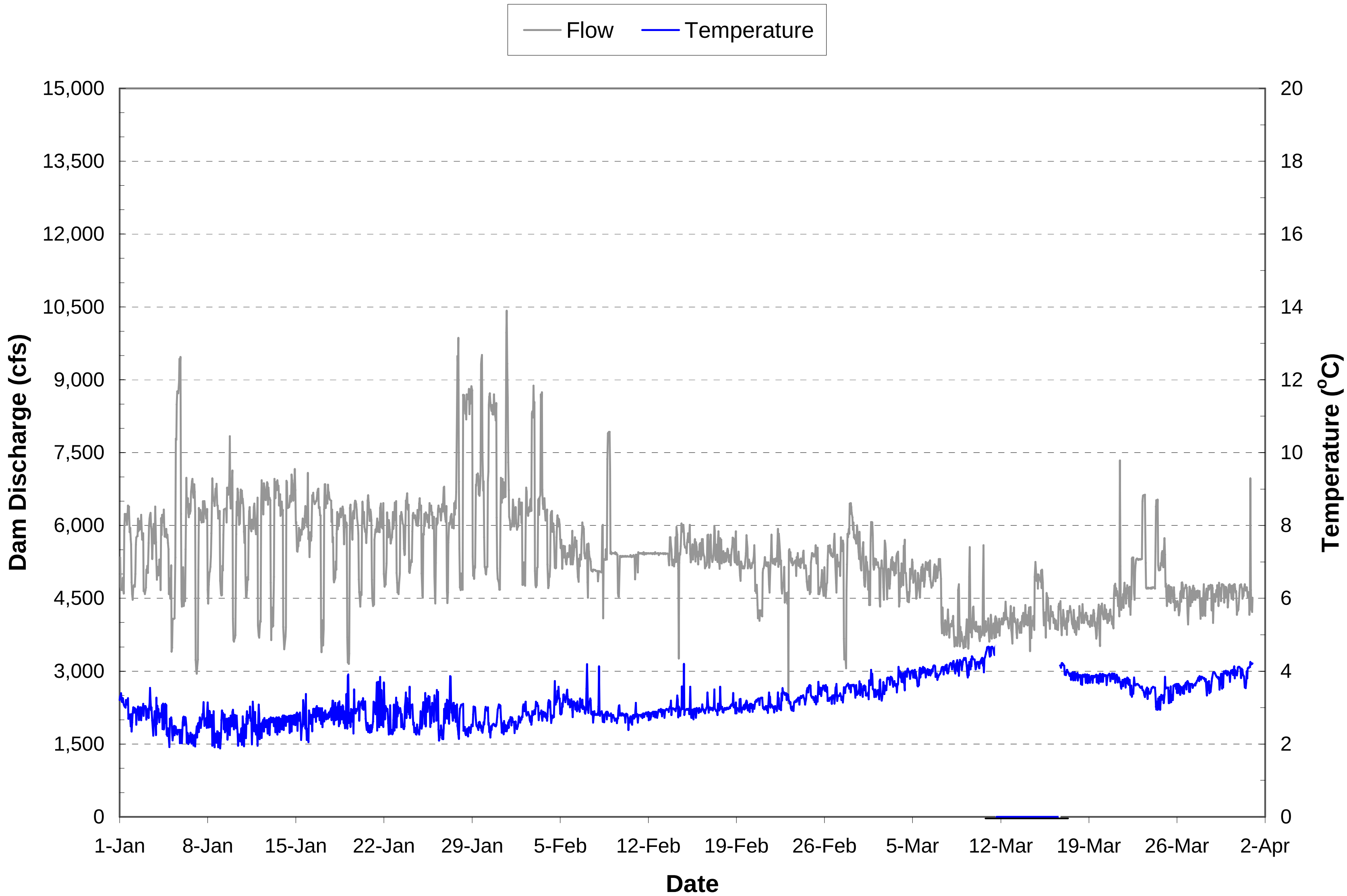


Plate 8. Hourly discharge and water temperature monitored at the Fort Peck power plant on water discharged through the dam during the period January through March 2005. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

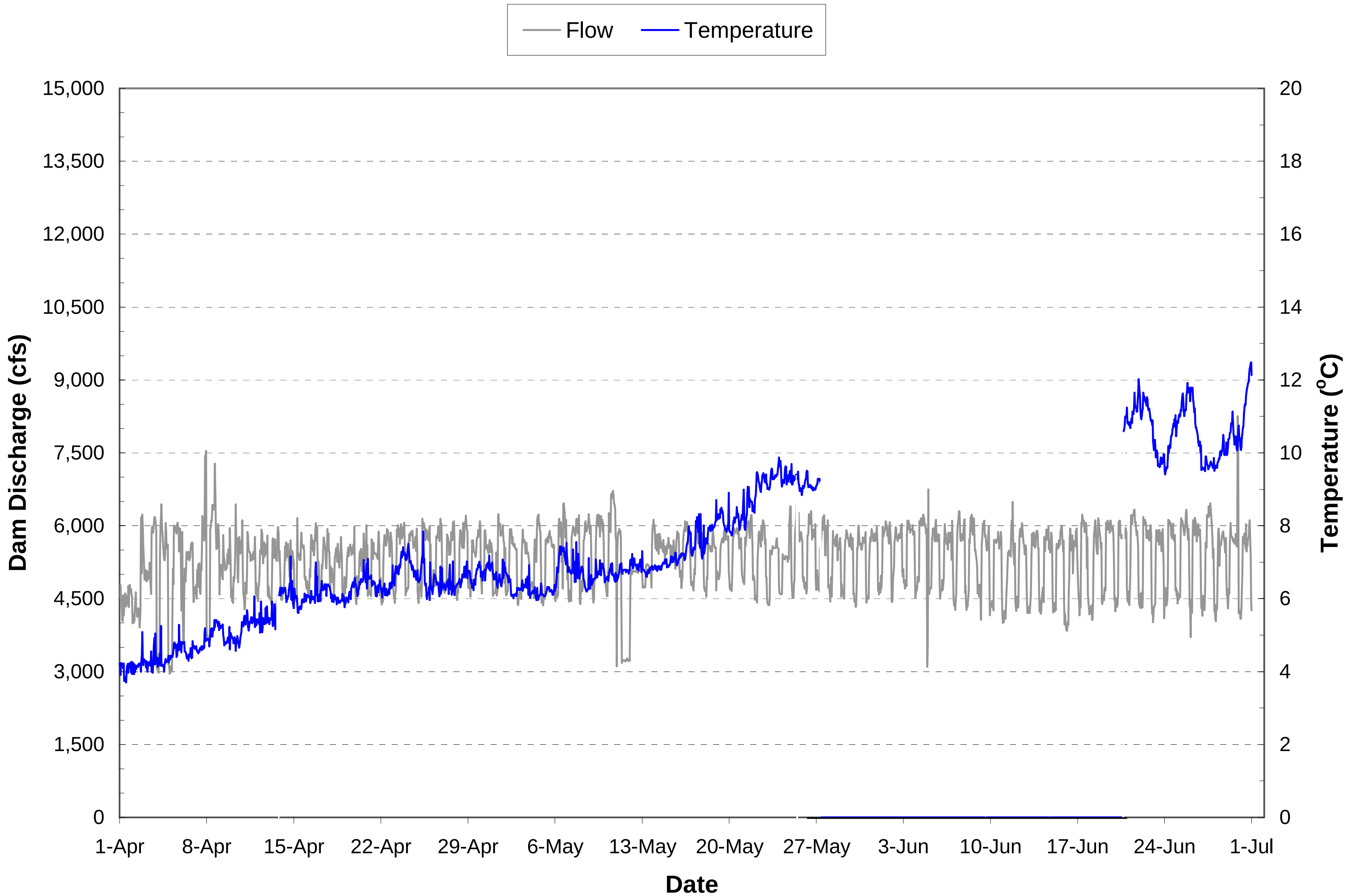


Plate 9. Hourly discharge and water temperature monitored at the Fort Peck power plant on water discharged through the dam during the period April through June 2005. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

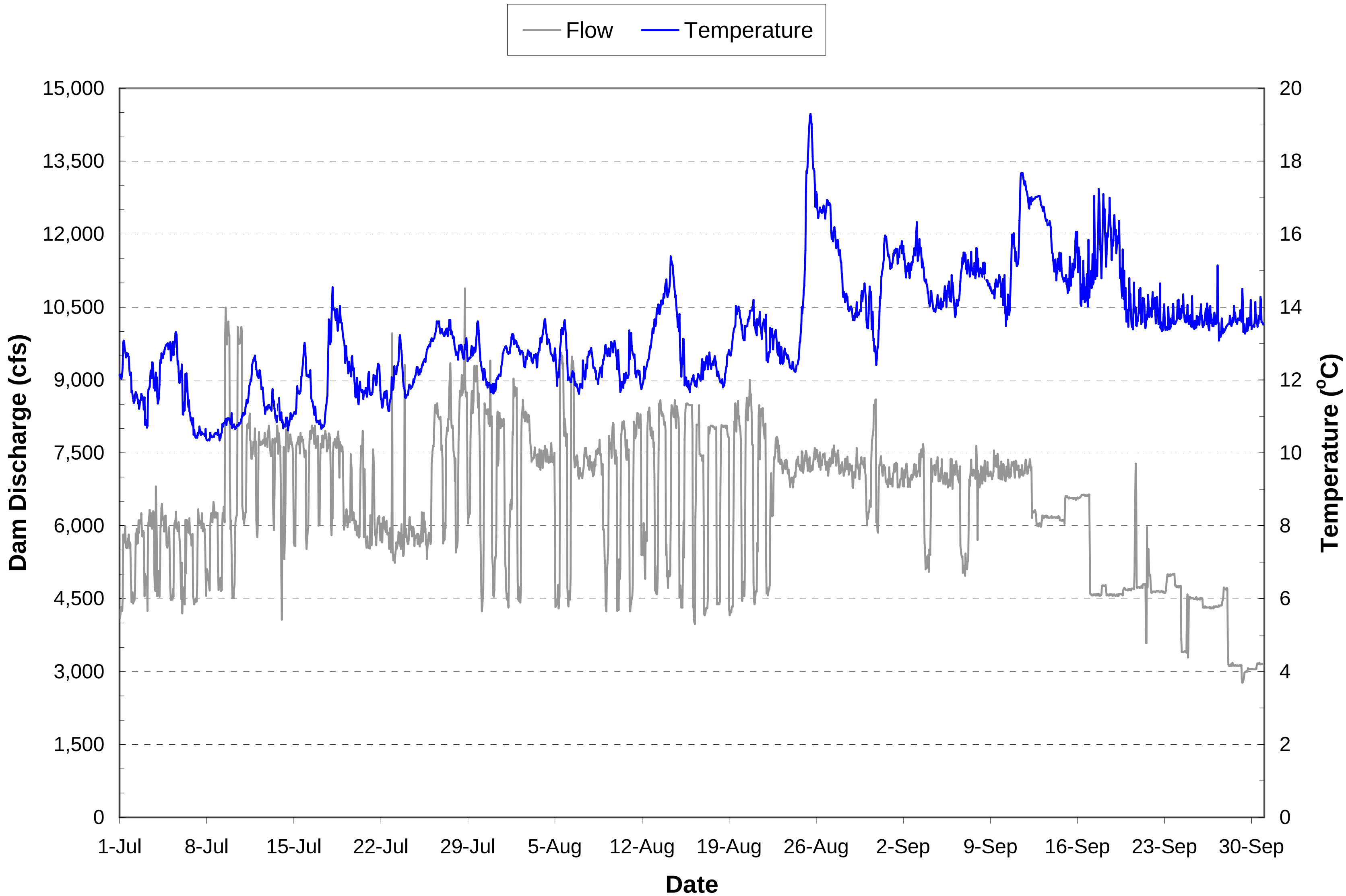


Plate 10. Hourly discharge and water temperature monitored at the Fort Peck power plant on water discharged through the dam during the period July through September 2005.

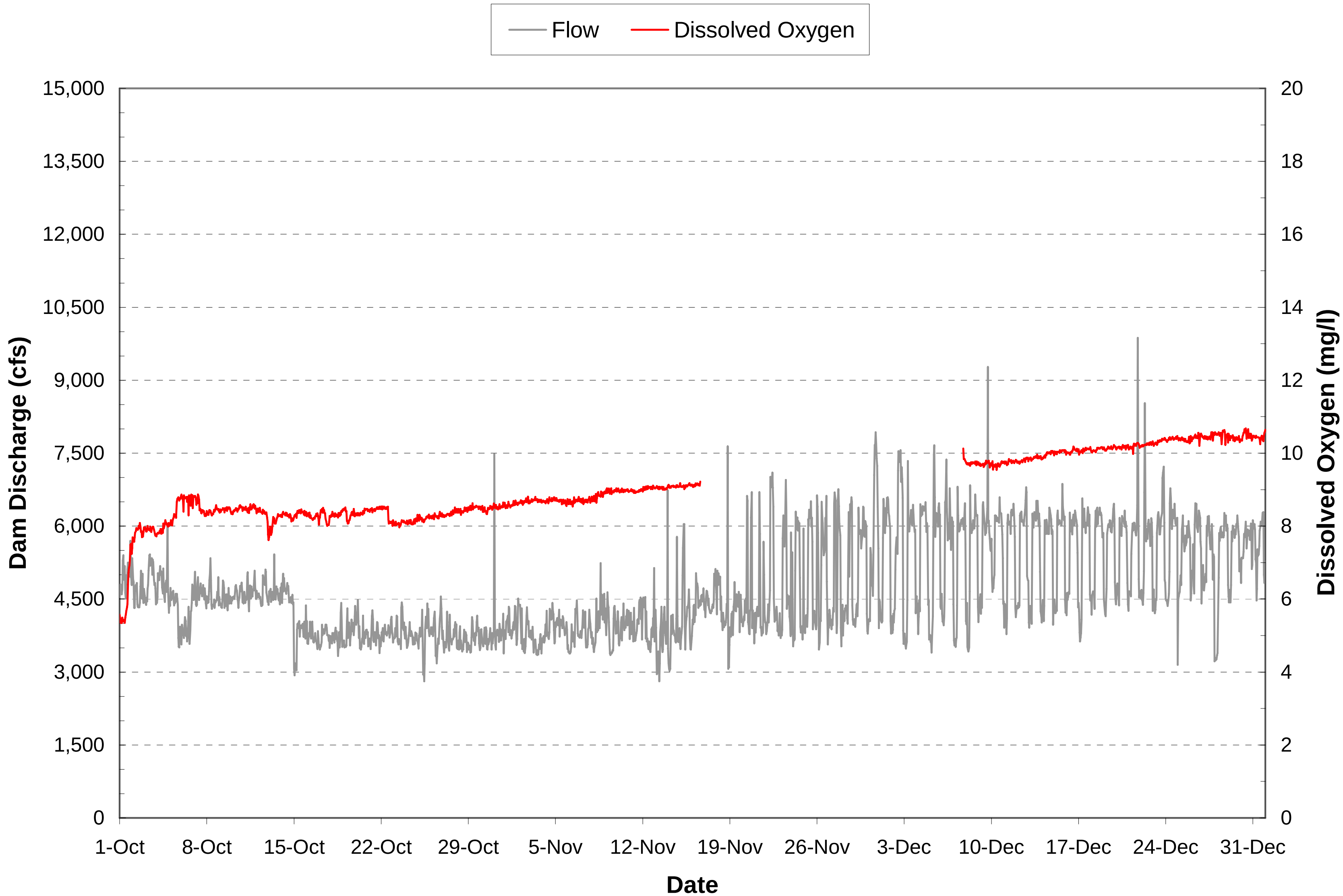


Plate 11. Hourly discharge and dissolved oxygen monitored at the Fort Peck power plant on water discharged through the dam during the period October through December 2004. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

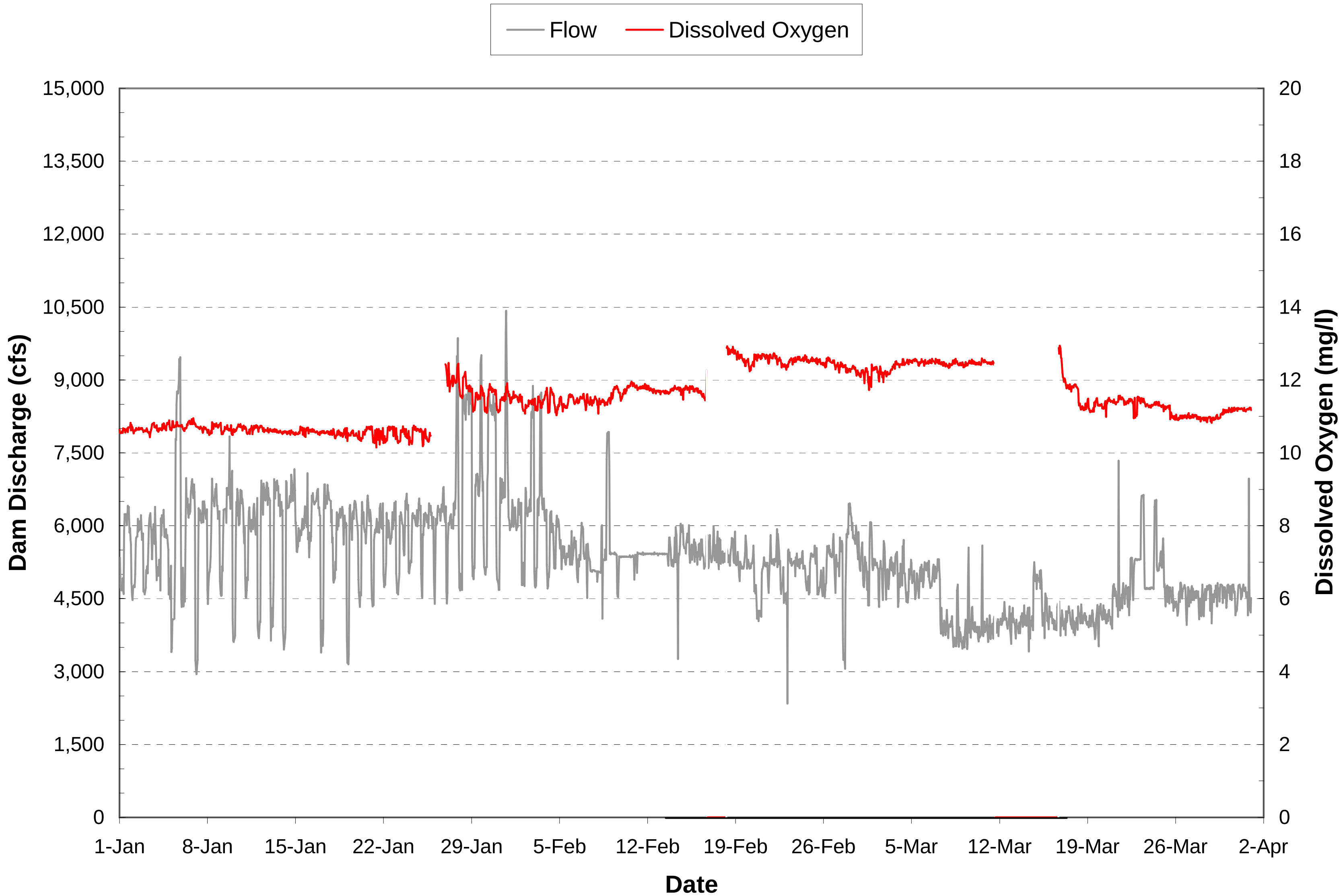


Plate 12. Hourly discharge and dissolved oxygen monitored at the Fort Peck power plant on water discharged through the dam during the period January through March 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

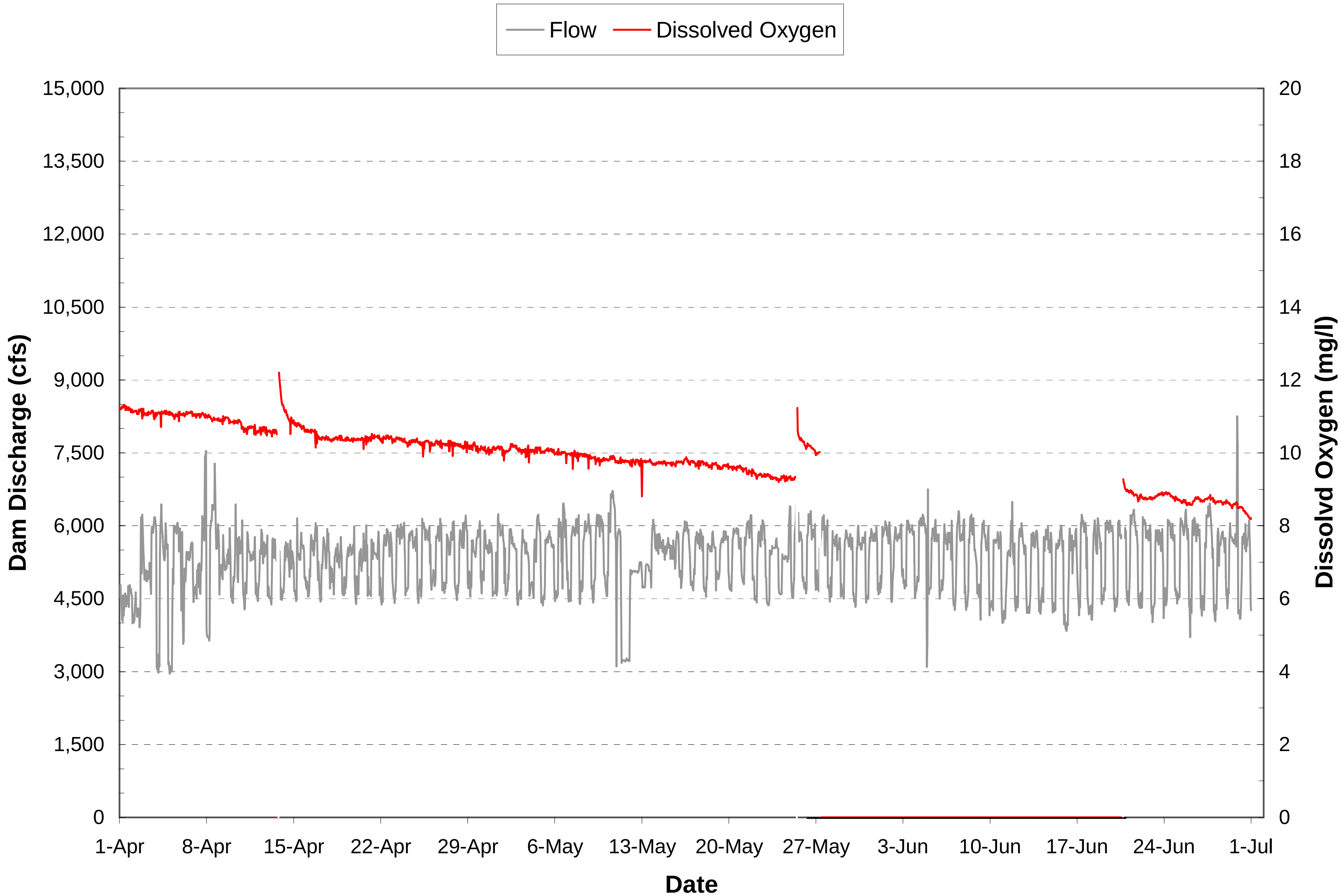


Plate 13. Hourly discharge and dissolved oxygen monitored at the Fort Peck power plant on water discharged through the dam during the period April through June 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

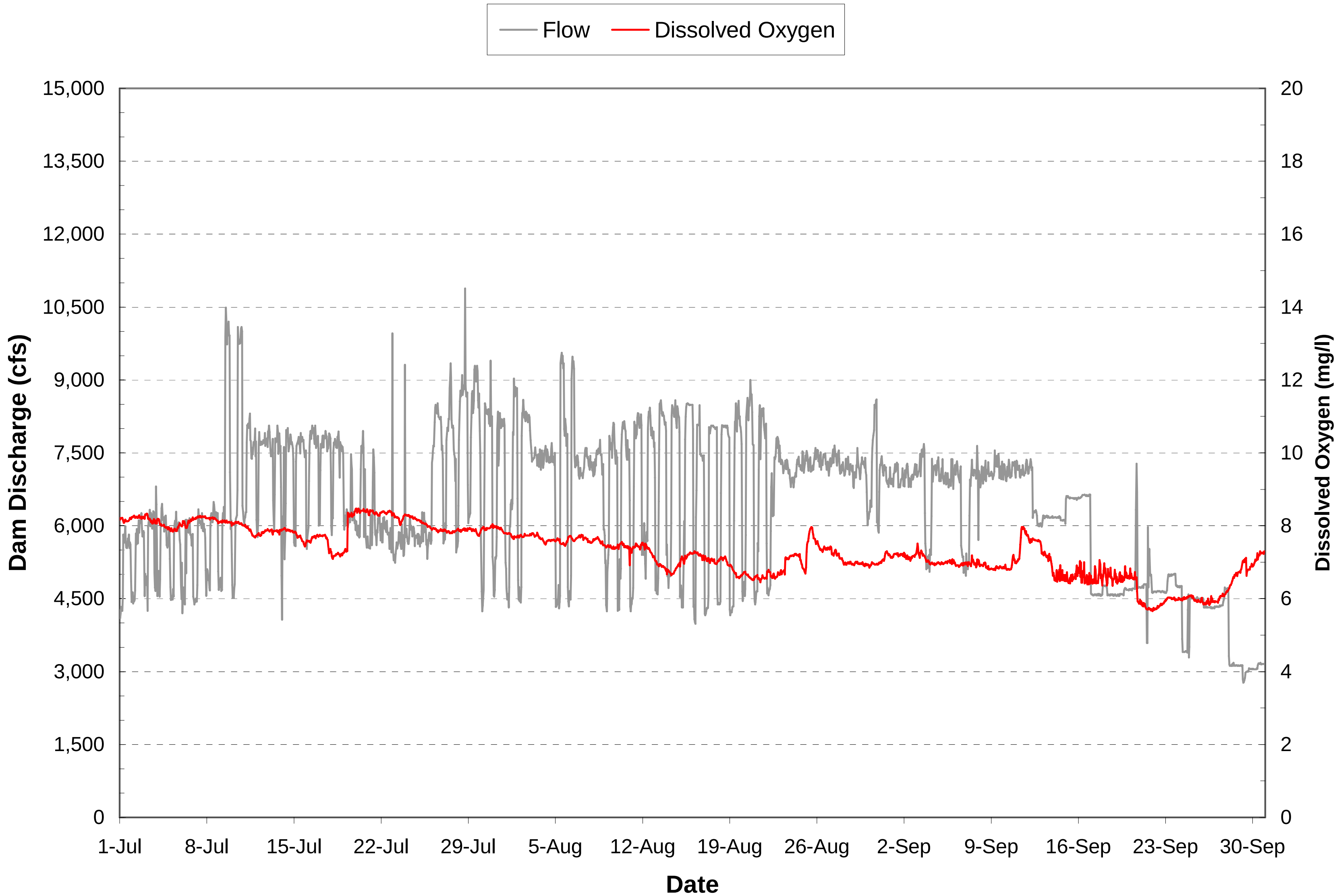


Plate 14. Hourly discharge and dissolved oxygen monitored at the Fort Peck power plant on water discharged through the dam during the period July through September 2005.

Plate 15. Summary of water quality conditions monitored in Garrison Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	26	1822.9	1824.3	1807.3	1834.4	-----	-----	-----
Water Temperature (C)	0.1	837	13.8	14.1	5.2	22.3	29.4[1] 15.0[1]	0 366	0% 44%
Dissolved Oxygen (mg/l)	0.1	837	8.3	8.2	3.9	12.2	≥ 5.0	19	2%
Dissolved Oxygen (% Sat.)	0.1	837	83.2	88.0	39.8	110.8	-----	-----	-----
Specific Conductance (umho/cm)	1	837	593	601	487	663	-----	-----	-----
pH (S.U.)	0.1	837	8.1	8.2	7.1	8 9	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	768	5.5	3.3	0.1	41.9	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	768	396	390	264	527	-----	-----	-----
Secchi Depth (in.)	1	26	127	120	54	228	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	168	169	153	181	-----	-----	-----
Ammonia, Total (mg/l)	0.01	44	0.20	0.09	n.d.	1.20	3.8 [2,3], 2.1 [2,4]	0	0%
Carbon, Total Organic (mg/l)	0.05	44	3.2	3.0	2.7	8.4	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	416	-----	n.d.	n.d.	9	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	17	-----	1	n.d.	12	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	31	444	420	363	572	-----	-----	-----
Hardness, Total (mg/l)	0.4	17	220	211	209	263	-----	-----	-----
Iron, Dissolved (ug/l)	40	19	-----	n.d.	n.d.	60	-----	-----	-----
Iron, Total (ug/l)	40	24	108	105	n.d.	305	1,000[3]	0	0%
Kjeldahl N, Total (mg/l)	0.1	50	-----	0.2	n.d.	1.6	-----	-----	-----
Manganese, Dissolved (ug/l)	1	19	-----	1	n.d.	6	-----	-----	-----
Manganese, Total (ug/l)	1	24	-----	6	n.d.	22	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	50	0.06	0.06	n.d.	0.18	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.01	35	-----	0.03	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	50	0.04	0.02	n.d.	0.41	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	50	-----	n.d.	n.d.	0.11	-----	-----	-----
Silica, Total (ug/l)	20	14	2,978	2,967	2,438	3,343	-----	-----	-----
Sulfate (mg/l)	0.1	36	165	162	149	188	-----	-----	-----
Suspended Solids, Total (mg/l)	4	50	-----	n.d.	n.d.	11	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	6[5]	0	0%
Arsenic, Dissolved (ug/l)	3	9	-----	n.d.	n.d.	n.d.	340[3], 150[4], 50[5]	0	0%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	4[5]	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	10.5[3], 4.4[4], 5[5]	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	34	3,323[3], 159[4], 100[5]	0	0%
Copper, Dissolved (ug/l)	2	8	-----	n.d.	n.d.	n.d.	28.3[3], 17.7[4], 1,000[5]	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Lead, Total (ug/l)	2	5	8.7	8.2	n.d.	20	211[3], 8 2[4], 15[5]	0/2/1	0%/40%/20%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Total (ug/l)	0.02	6	-----	n.d.	n.d.	0.02	1.7[3], 0.91[4], 0.05[5]	0	0%
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	17	882[3], 98[4], 100[5]	0	0%
Selenium, Total (ug/l)	4	4	-----	n.d.	n.d.	n.d.	20[3], 5[4], 50[5]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	14.7[3]	0	0%
Zinc, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Total (ug/l)	3	4	6.6	3.9	n.d.	17	226[3,4], 9,100[5]	0	0%
Alachlor, Total (ug/l)	0.05	10	-----	n.d.	n.d.	n.d.	2	0	0%
Atrazine, Total (ug/l)	0.05	10	-----	n.d.	n.d.	0.13	3	0	0%
Metolachlor, Total (ug/l)	0.05	10	-----	n.d.	n.d.	0.06	40	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.	n.d.	n.d.	****	0	0%
Microcystins, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1]Numeric temperature criterion given in North Dakota water quality standards is 29.4 C. No specific numeric temperature criteria are identified for coldwater aquatic life; however, ≤15 C has been identified by North Dakota as the temperature needed to support optimal coldwater habitat in Garrison Reservoir.

[2]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.2 and 14.1 respectively.

[3] Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)

[4] Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)

[5]Human health criterion for surface waters.

Note: North Dakota's WQS criteria for metals are based on total recoverable, most analyzed metal concentrations were dissolved. Listed criteria are given for comparison and were calculated using the median hardness of 211 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 16. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division, and dominant taxa present for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site at Garrison Reservoir during the period 2004 through 2005.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
May 2004	18,358,561	3	0 58	0	-----	0	-----	1	0.03	1	0.02	1	0.37	0	-----	1.15
Jun 2004	1,982,256	2	0 53	0	-----	0	-----	1	0.35	2	0.12	0	-----	0	-----	1.15
Jul 2004	87,982,899	5	0.87	1	0.01	0	-----	1	0.11	3	<0.01	0	-----	0	-----	1.45
Aug 2004	102,328,294	5	0.83	2	0.01	0	-----	2	0.16	2	<0.01	0	-----	0	-----	1.03
Sep 2004	207,432,106	6	0.84	3	0.02	1	0.01	2	0.13	2	<0.01	1	<0.01	0	-----	1.62
May 2005	1,366,154,039	8	0.99	4	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	1.41
Jun 2005	6,163,686	1	0.88	0	-----	0	-----	0	-----	2	0.12	0	-----	0	-----	0.46
Jul 2005	56,944,302	7	0 57	2	0.19	0	-----	2	0.24	1	<0.01	0	-----	0	-----	1.82
Aug 2005	103,732,272	4	0.42	4	0.11	0	-----	1	0.29	2	<0.01	2	0.18	0	-----	1.93
Sep 2005	104,058,345	7	0.48	3	0.23	0	-----	2	0.29	2	<0.01	0	-----	0	-----	1.87
Mean*	**205,513,676**	**4.8**	**0.70**	**1.9**	**0.08**	**0.2**	**0.01**	**1.3**	**0.18**	**1.7**	**0.03**	**0.4**	**0.18**	**0**	**-----**	**1.39**

* Mean percent composition represents the mean when taxa of that division are present.

Date	Division	Dominant Taxa*	Percent of Total Biovolume	Date	Division	Dominant Taxa	Percent of Total Biovolume
May 2004	Bacillariophyta	*Fragilaria crotonensis*	0.49	May 2005	Bacillariophyta	*Fragilaria crotonensis*	0.55
	Pyrrophyta	*Peridinium inconspicuum*	0.37		Bacillariophyta	*Cyclotella spp.*	0.15
					Bacillariophyta	*Tabellaria fenestrata*	0.13
June 2004	Bacillariophyta	*Synedra spp.*	0.49	June 2005	Bacillariophyta	*Stephanodiscus spp.*	0.88
	Cryptophyta	*Rhodomonas minuta*	0.35				
	Cyanobacteria	*Aphanocapsa spp.*	0.11				
July 2004	Bacillariophyta	*Asterionella formossa*	0.42	July 2005	Bacillariophyta	*Asterionella formossa*	0.28
	Bacillariophyta	*Cyclotella spp.*	0.23		Bacillariophyta	*Fragilaria crotonensis*	0.23
	Bacillariophyta	*Fragilaria crotonensis*	0.19		Cryptophyta	*Rhodomonas minuta*	0.22
					Chlorophyta	*Chlamydomonas spp.*	0.13
August 2004	Bacillariophyta	*Fragilaria crotonensis*	0.67	August 2005	Cryptophyta	*Rhodomonas minuta*	0.29
	Cryptophyta	*Cryptomonas spp.*	0.15		Bacillariophyta	*Asterionella formossa*	0.23
	Bacillariophyta	*Asterionella formossa*	0.13		Pyrrophyta	*Ceratium hirundinella*	0.16
					Bacillariophyta	*Melosira varians*	0.12
September 2004	Bacillariophyta	*Asterionella formossa*	0.39	September 2005	Bacillariophyta	*Fragilaria crotonensis*	0.29
	Bacillariophyta	*Fragilaria crotonensis*	0.30		Cryptophyta	*Rhodomonas minuta*	0.25
	Cryptophyta	*Rhodomonas minuta*	0.13		Chlorophyta	*Chlamydomonas spp.*	0.17

* Dominant taxa are genera or species (depending on identification level) that comprised more than 10% of the total sample biovolume.

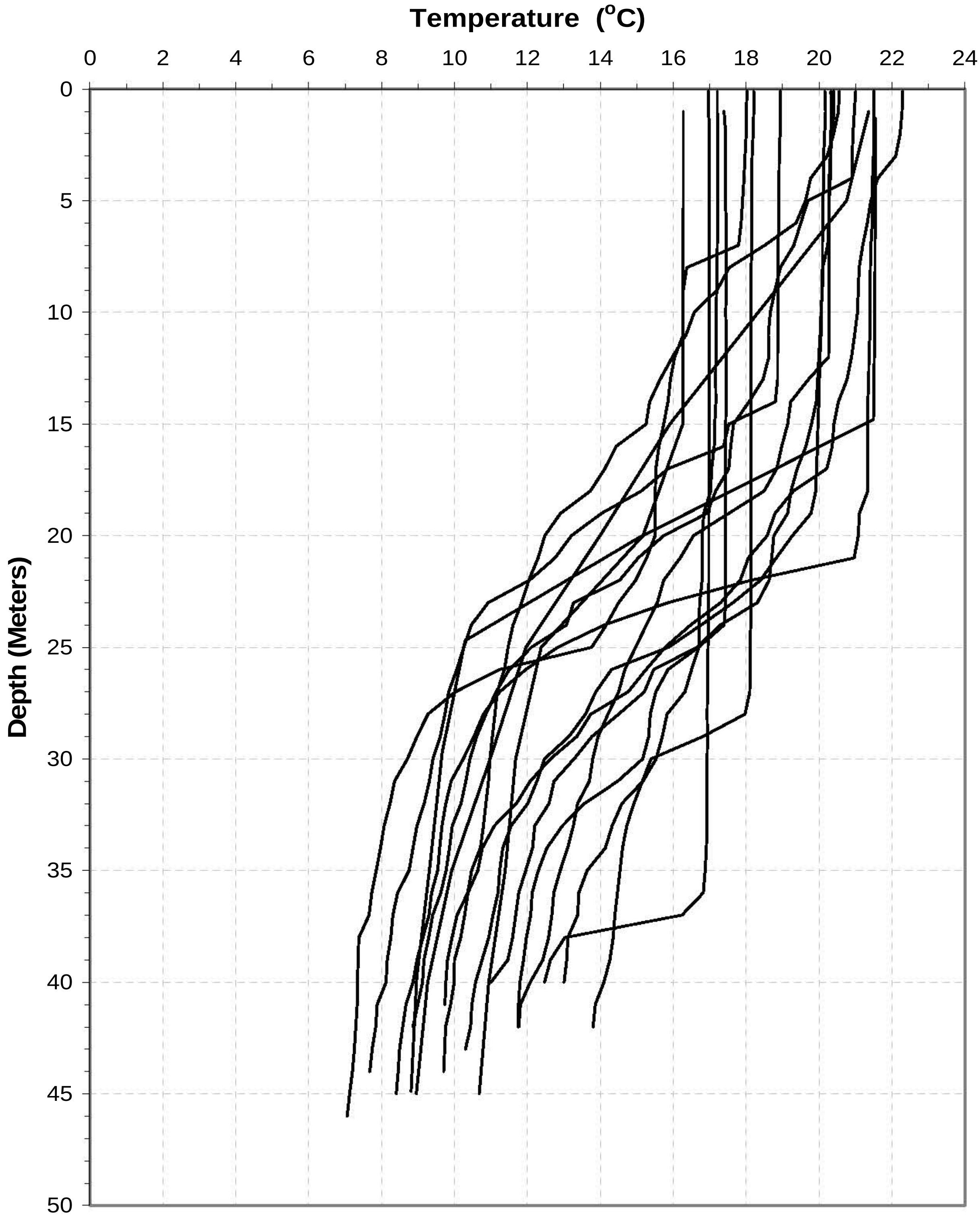


Plate 17. Temperature depth profiles for Garrison Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005.

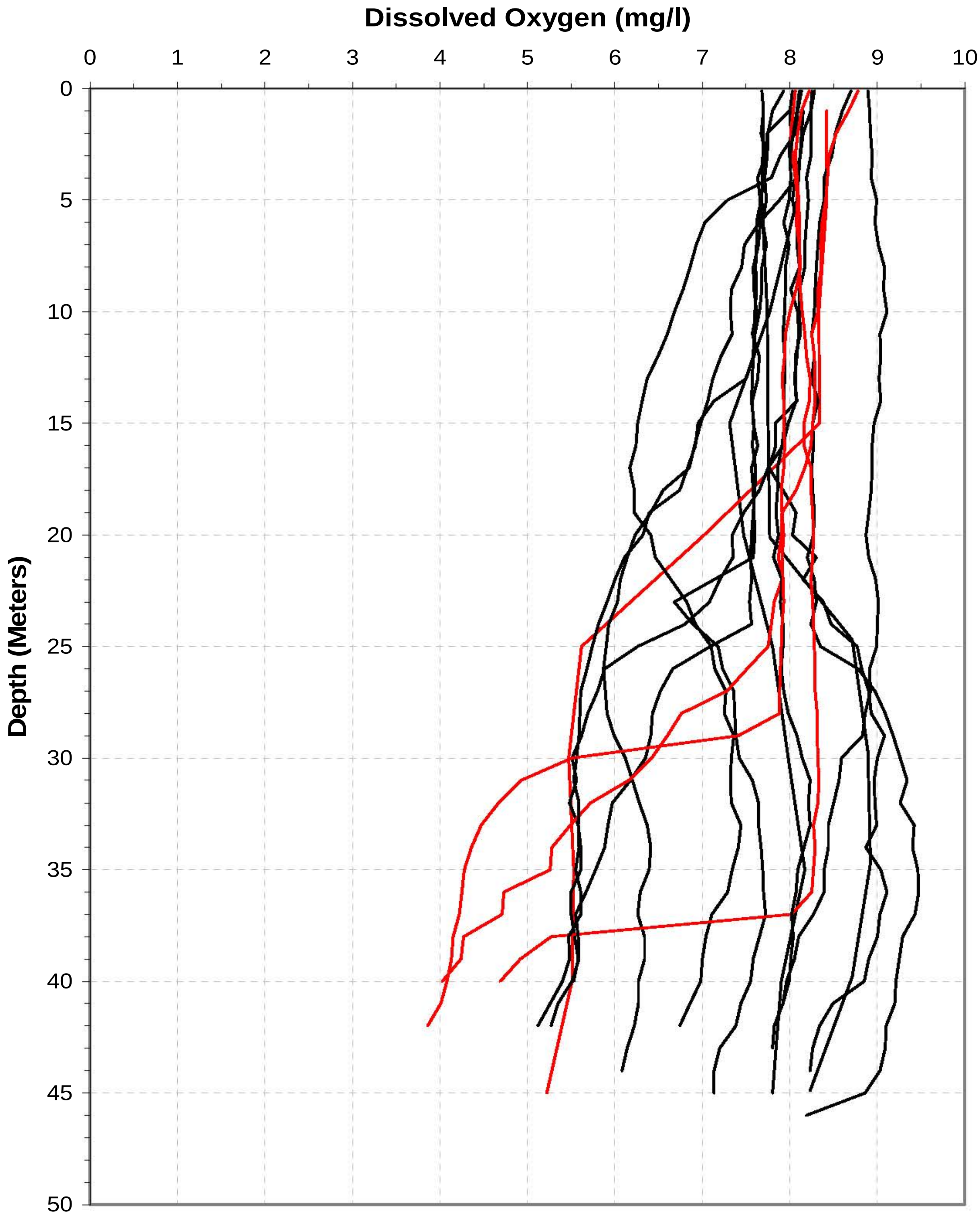


Plate 18. Dissolved oxygen depth profiles for Garrison Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005. (Note: Red profiles were measured in the month of September.)

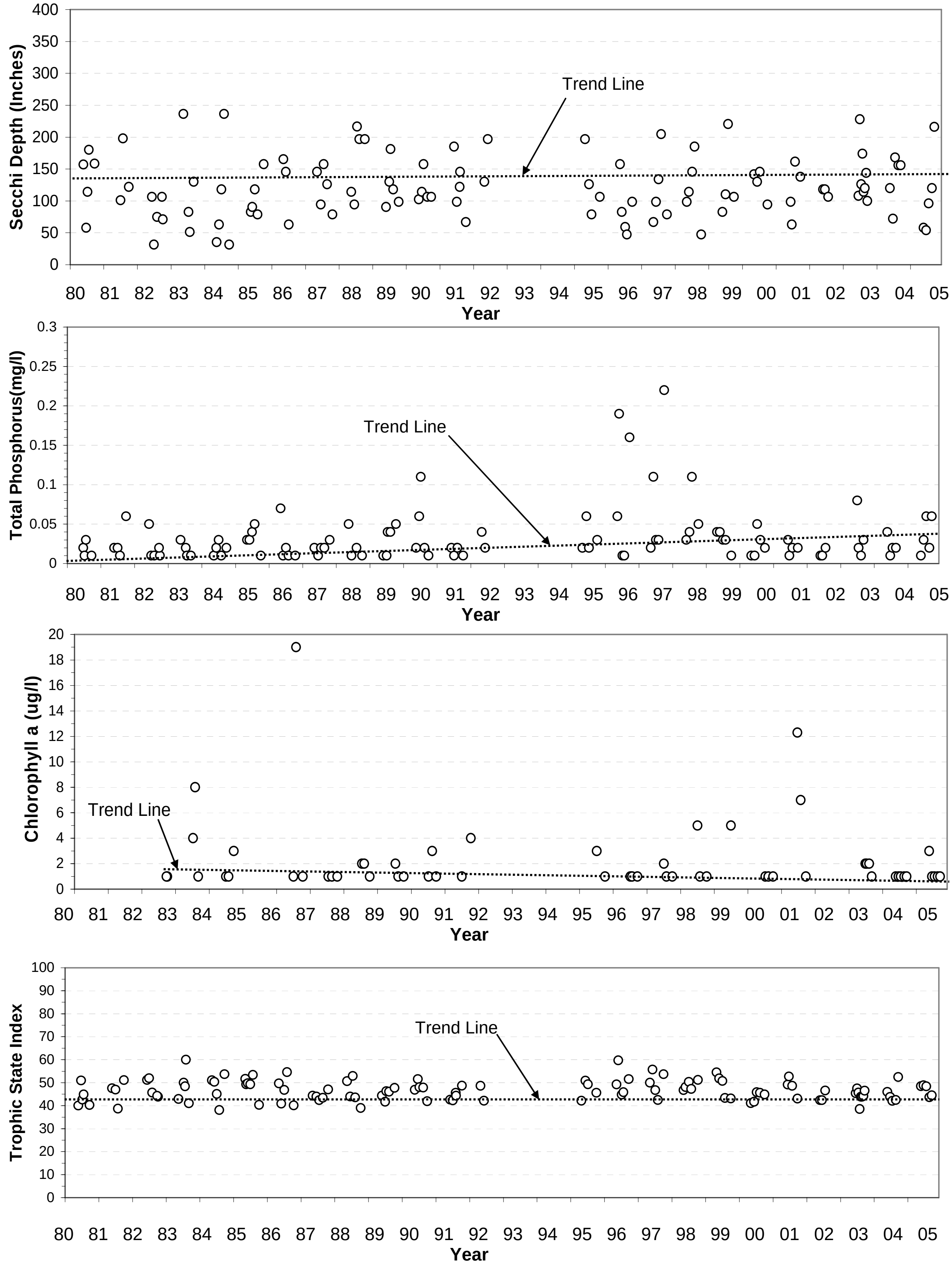


Plate 19. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Garrison Reservoir at the near-dam, ambient site over the 26-year period of 1980 to 2005.

Plate 20. Summary of water quality conditions monitored on water discharged through Garrison Dam during the 1-year period of October 1, 2004 through September 30, 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Dam Discharge (cfs)	1	8,760	14,478	13,140	4,830	30,600	-----	-----	-----
Water Temperature (C)	0.1	8,063	7.8	7.8	0.1	18.7	29.4[1] 15.0[1]	0 1,270	0% 16%
Dissolved Oxygen (mg/l)	0.1	8,063	9.9	10.3	4.5	15.2	≥ 5.0	3	<1%
Dissolved Oxygen (% Sat.)	0.1	6,344	89.4	90.9	46.8	111.9	-----	-----	-----
Specific Conductance (umho/cm)	1	6,344	496	501	415	575	-----	-----	-----
pH (S.U.)	0.1	6,344	8.6	8.5	7.9	9.0	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	11	171	170	166	180	-----	-----	-----
Ammonia, Total (mg/l)	0.01	11	0.08	0.04	n.d.	0.22	2.1 [2,3], 0.9 [2,4]	0	0%
Carbon, Total Organic (mg/l)	0.05	10	2.93	2.95	2 50	3.30	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	11	377	388	236	450	-----	-----	-----
Hardness, Total (mg/l)	0.4	2	208	208	204	212	-----	-----	-----
Iron, Dissolved (ug/l)	40	10	-----	n.d.	n.d.	n.d.	-----	-----	-----
Iron, Total (ug/l)	40	11	259	199	n.d.	961	1,000[3]	0	0%
Kjeldahl N, Total (mg/l)	0.1	10	0.3	0.2	0.2	0.9	-----	-----	-----
Manganese, Dissolved (ug/l)	1	10	2	2	n.d.	4	-----	-----	-----
Manganese, Total (ug/l)	1	11	19	14	3	64	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	11	0.07	0.06	n.d.	0.15	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.01	5	0.03	0.03	0.01	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	11	0.06	0.03	n.d.	0.30	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	11	-----	n.d.	n.d.	0.25	-----	-----	-----
Sulfate (mg/l)	0.1	11	168	170	128	180	-----	-----	-----
Suspended Solids, Total (mg/l)	4	11	-----	n.d.	n.d.	21	-----	-----	-----
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6[5]	0	0%
Arsenic, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	n.d.	340[3], 150[4], 50[5]	0	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4[5]	0	0%
Cadmium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	10.5[3], 4.4[4], 5[5]	0	0%
Chromium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	3,323[3], 159[4], 100[5]	0	0%
Copper, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	28.3[3], 17.7[4], 1,000[5]	0	0%
Lead, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	211[3], 8.2[4], 15[5]	0	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	-----	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.7[3], 0.91[4], 0.05[5]	0	0%
Nickel, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	n.d.	882[3], 98[4], 100[5]	0	0%
Selenium, Total (ug/l)	4	2	-----	n.d.	n.d.	n.d.	20[3], 5[4], 50[5]	0	0%
Silver, Dissolved (ug/l)	1	2	-----	n.d.	n.d.	n.d.	14.7	0	0%
Zinc, Dissolved (ug/l)	3	2	5	5	4	6	226[3,4], 9,100[5]	0	0%
Pesticide Scan (ug/l)***	0.05	1	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1] Numeric temperature criterion given in North Dakota water quality standards is 29.4 C. No specific numeric temperature criteria are identified for coldwater aquatic life; however, ≤15 C has been identified by North Dakota as the temperature needed to support optimal coldwater habitat in Garrison Reservoir.

[2] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.5 and 7.8 respectively.

[3] Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)

[4] Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)

[5] Human health criterion for surface waters.

Note: North Dakota's WQS criteria for metals are based on total recoverable, most analyzed metal concentrations were dissolved. Listed criteria are given for comparison and were calculated using the median hardness of 208 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

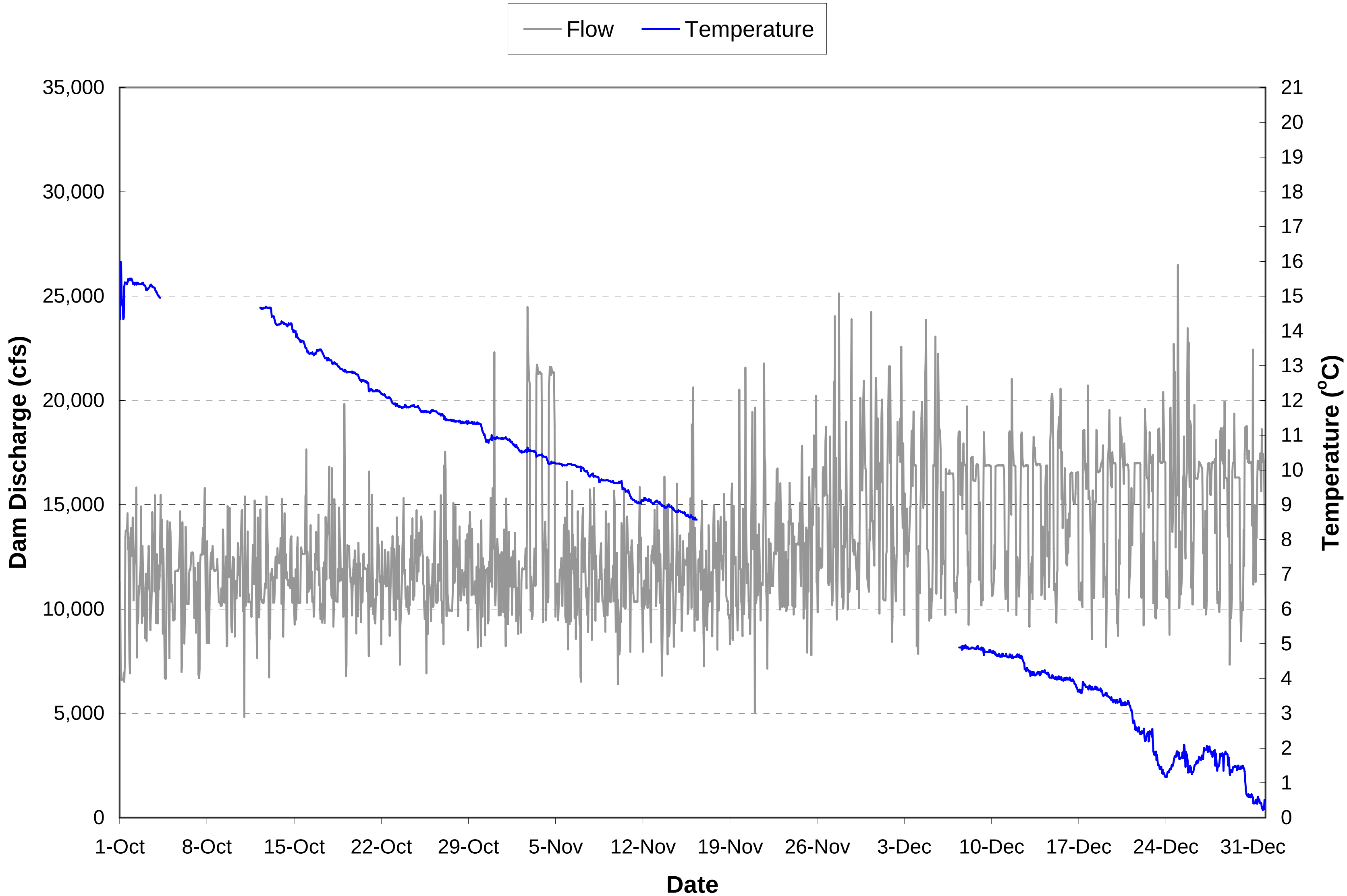


Plate 21. Hourly discharge and water temperature monitored at the Garrison power plant on water discharged through the dam during the period October through December 2004. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

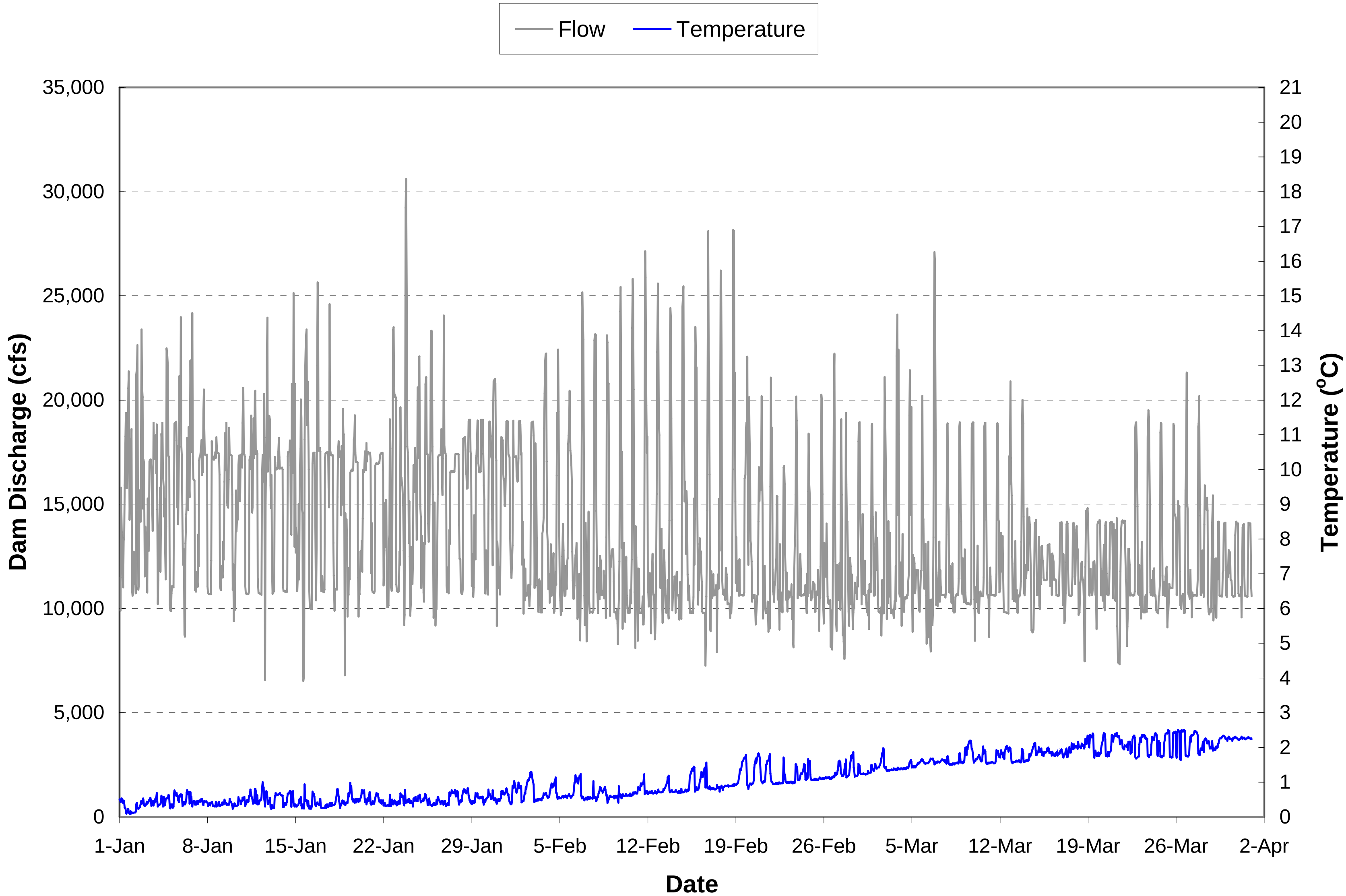


Plate 22. Hourly discharge and water temperature monitored at the Garrison power plant on water discharged through the dam during the period January through March 2005.

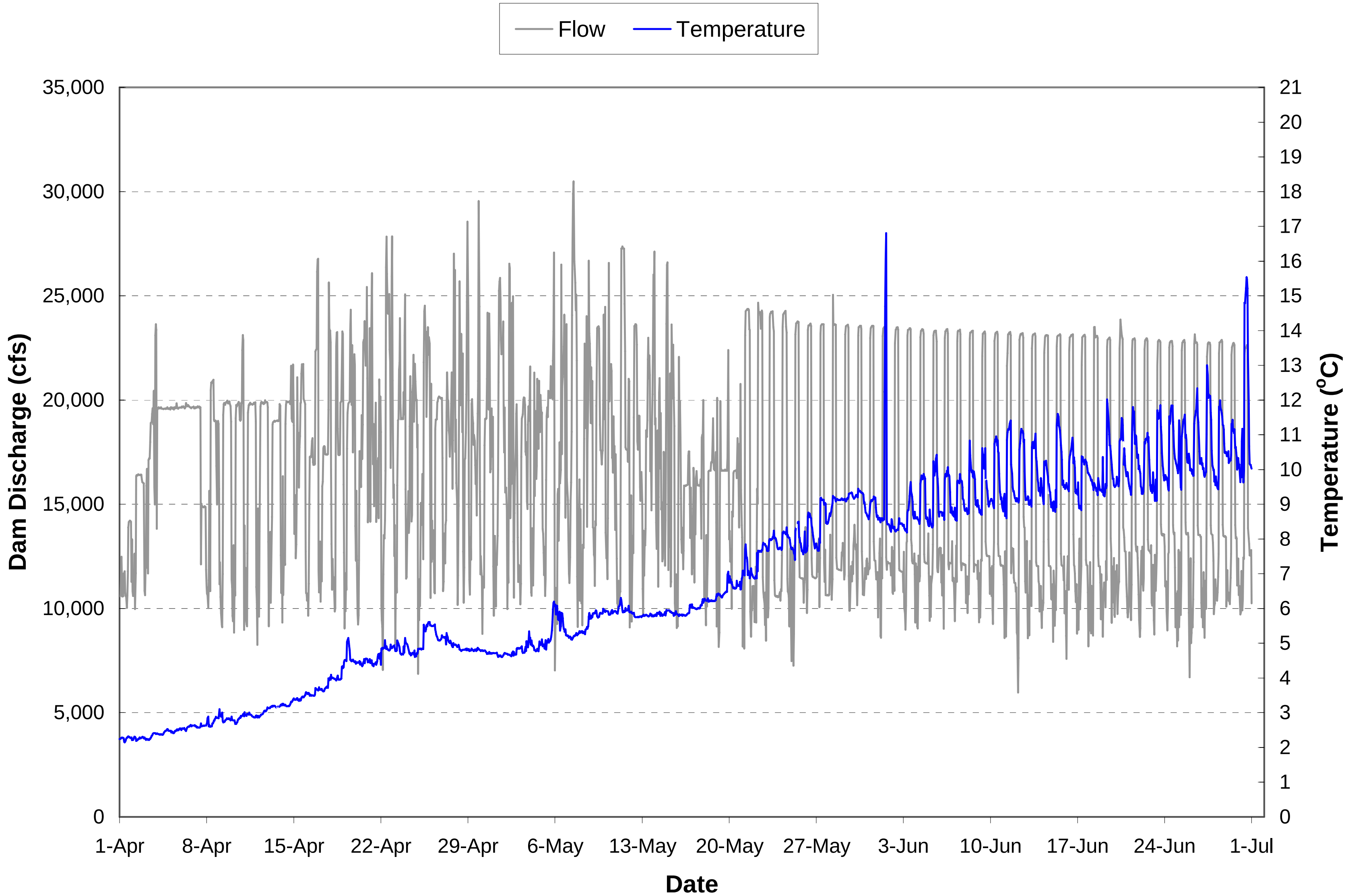


Plate 23. Hourly discharge and water temperature monitored at the Garrison power plant on water discharged through the dam during the period April through June 2005.

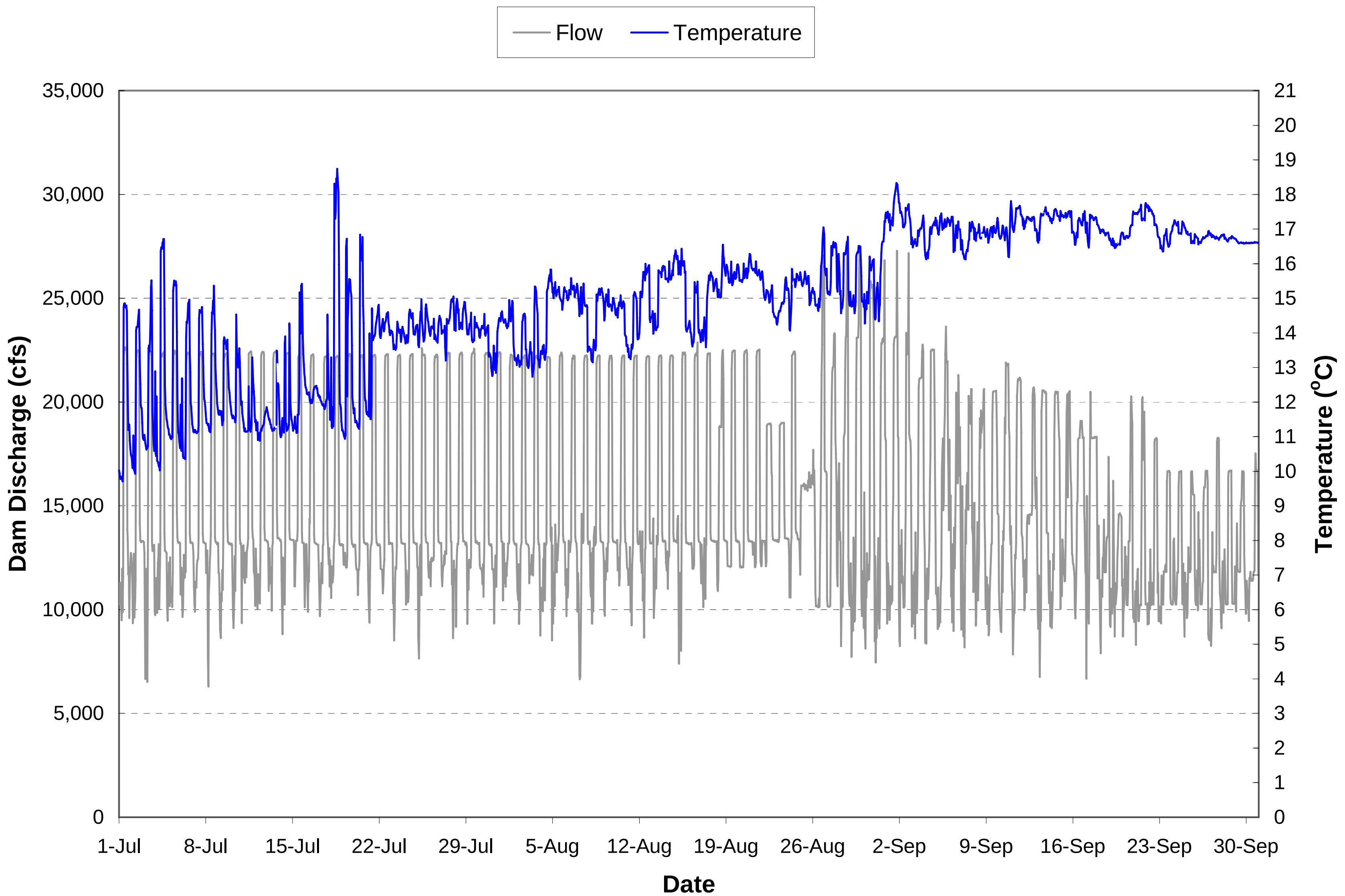


Plate 24. Hourly discharge and water temperature monitored at the Garrison power plant on water discharged through the dam during the period July through September 2005.

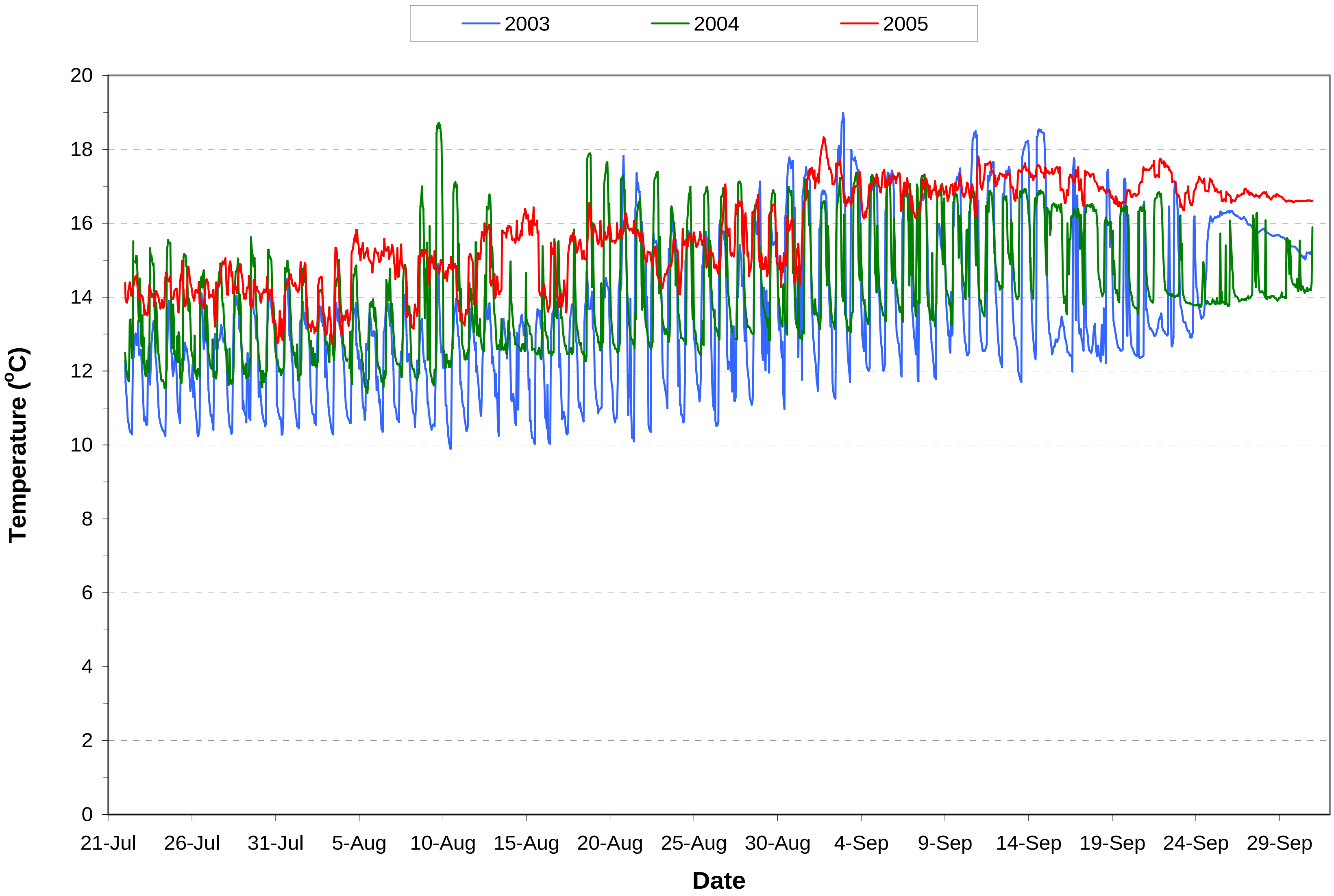


Plate 25. Temperature of water discharged through Garrison Dam during the period July 22 through September 30 in 2003, 2004, and 2005.

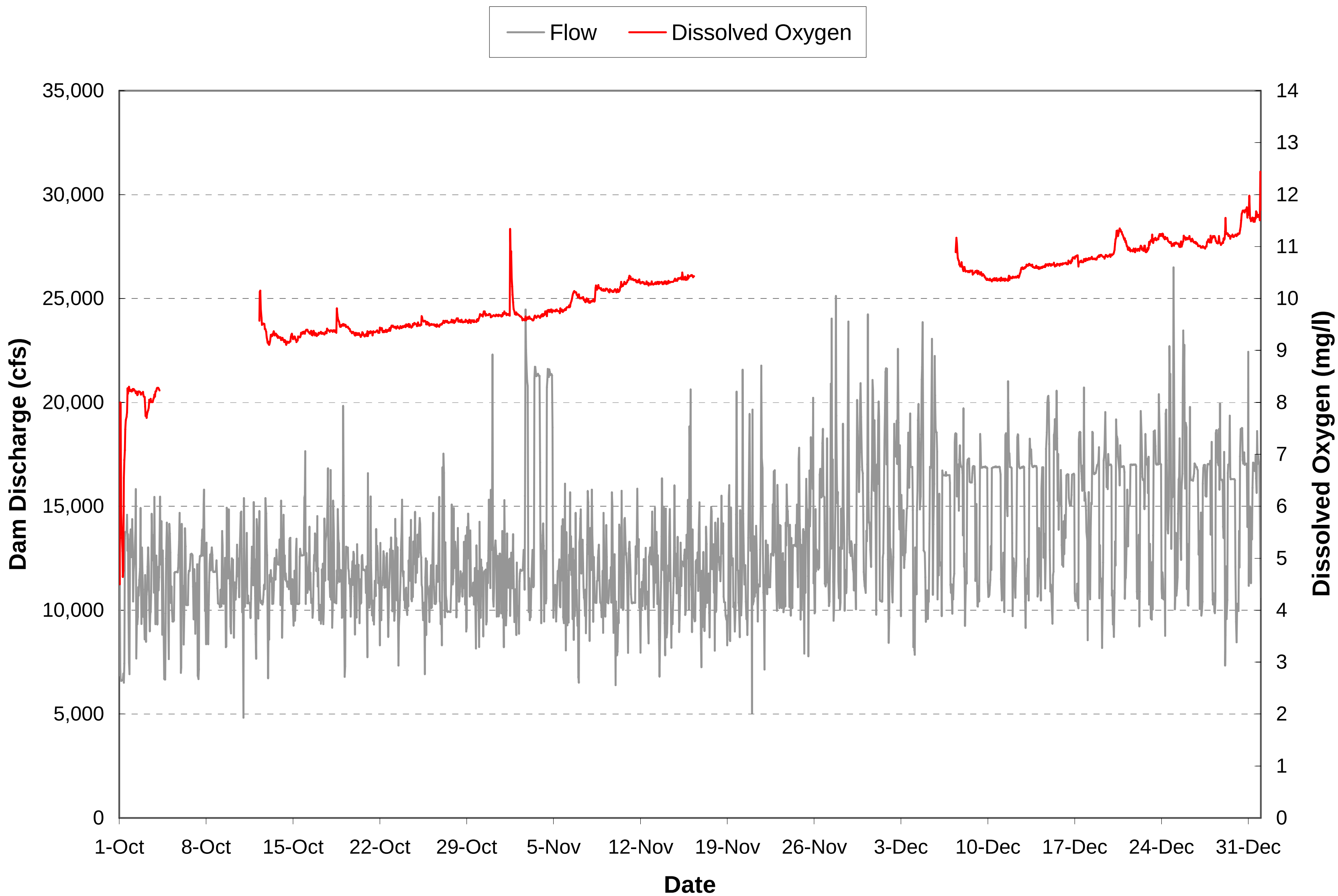


Plate 26. Hourly discharge and dissolved oxygen concentrations monitored at the Garrison power plant on water discharged through the dam during the period October through December 2004. (Note gaps in Dissolved oxygen plot represents periods when monitoring equipment was not operational.)

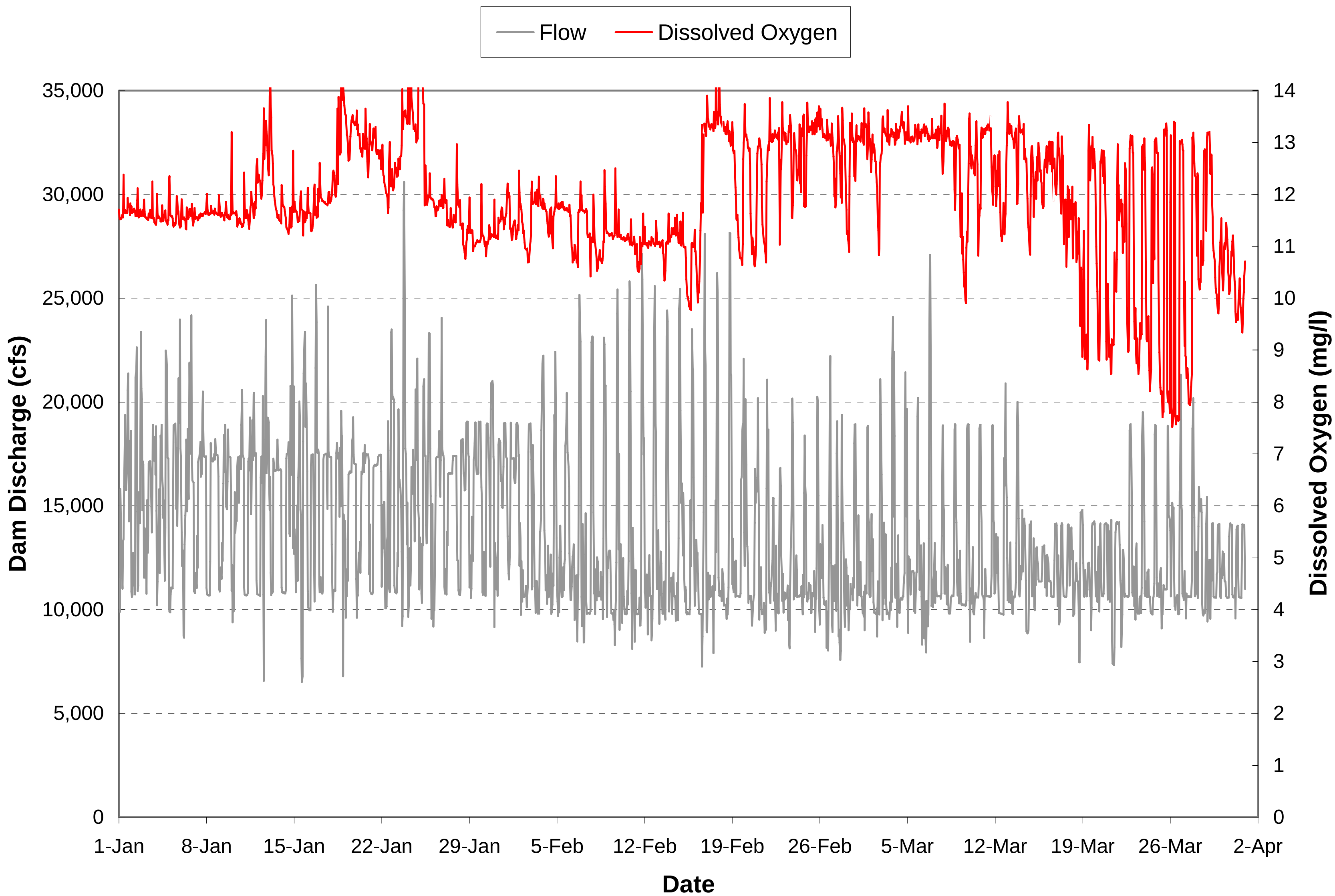


Plate 27. Hourly discharge and dissolved oxygen concentrations monitored at the Garrison power plant on water discharged through the dam during the period January through March 2005.

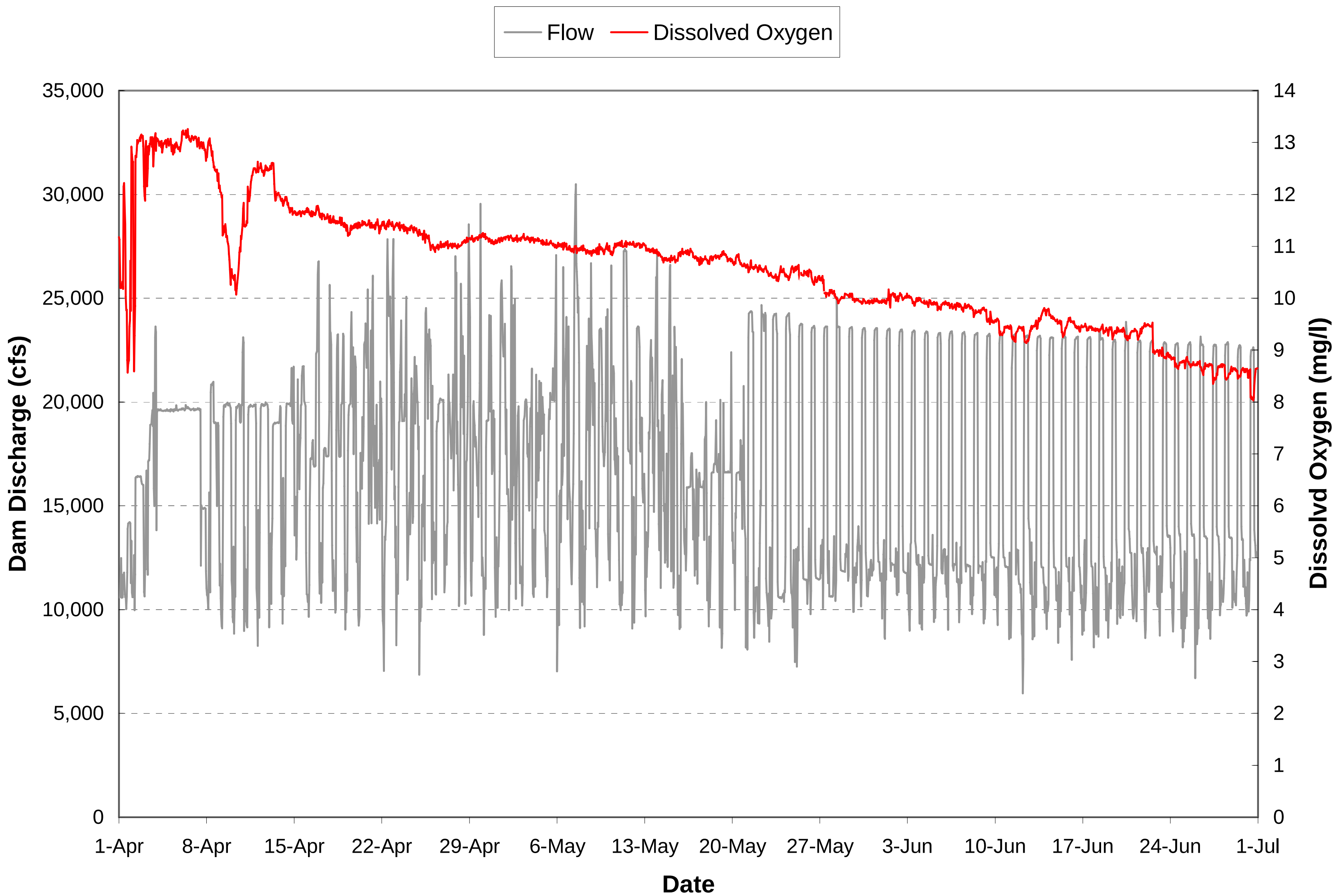


Plate 28. Hourly discharge and dissolved oxygen concentrations monitored at the Garrison power plant on water discharged through the dam during the period April through June 2005.

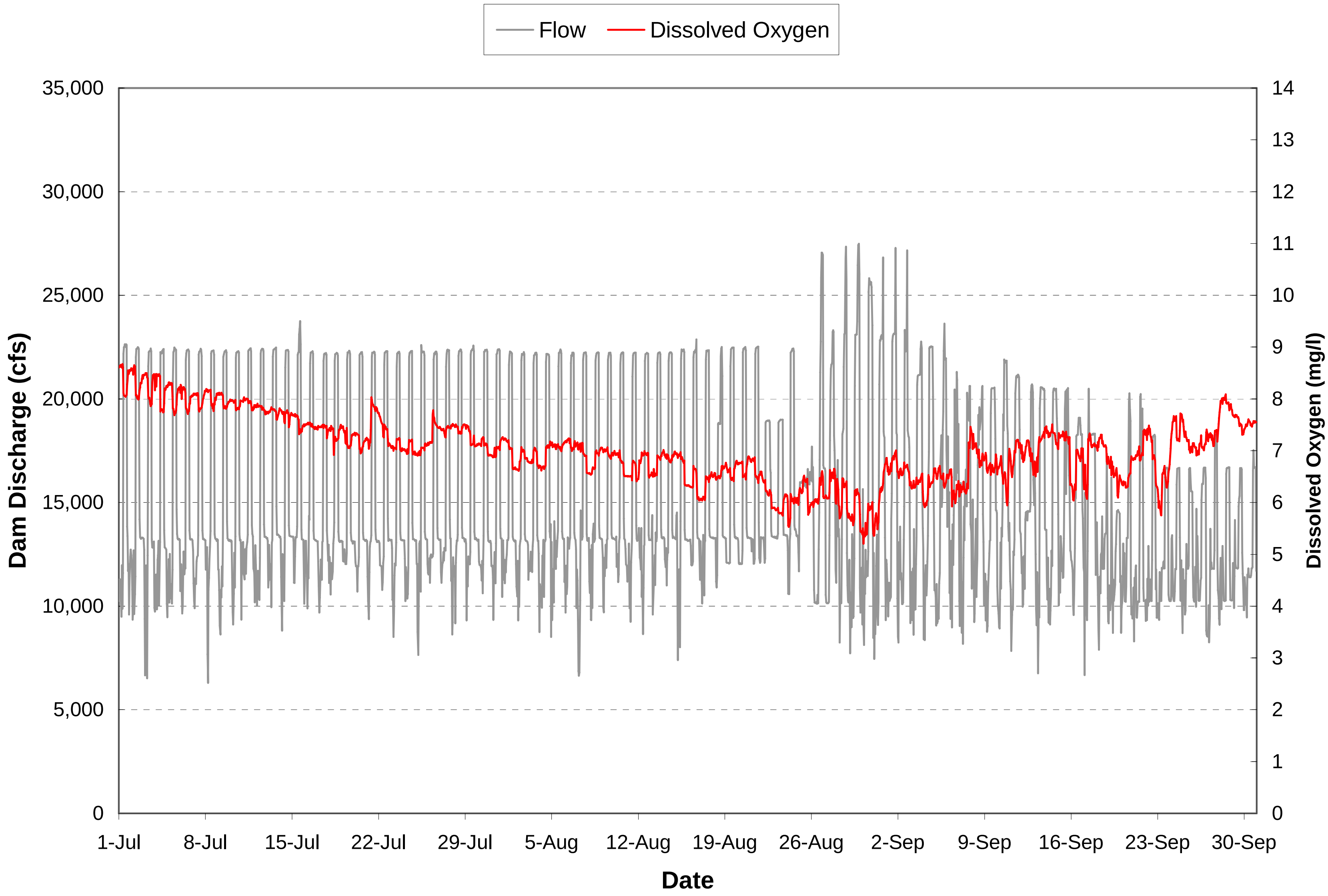


Plate 29. Hourly discharge and dissolved oxygen concentrations monitored at the Garrison power plant on water discharged through the dam during the period July through September 2005.

Plate 30. Dissolved oxygen concentration of water discharged through Garrison Dam during the period July 22 through September 30 in 2003, 2004, and 2005.

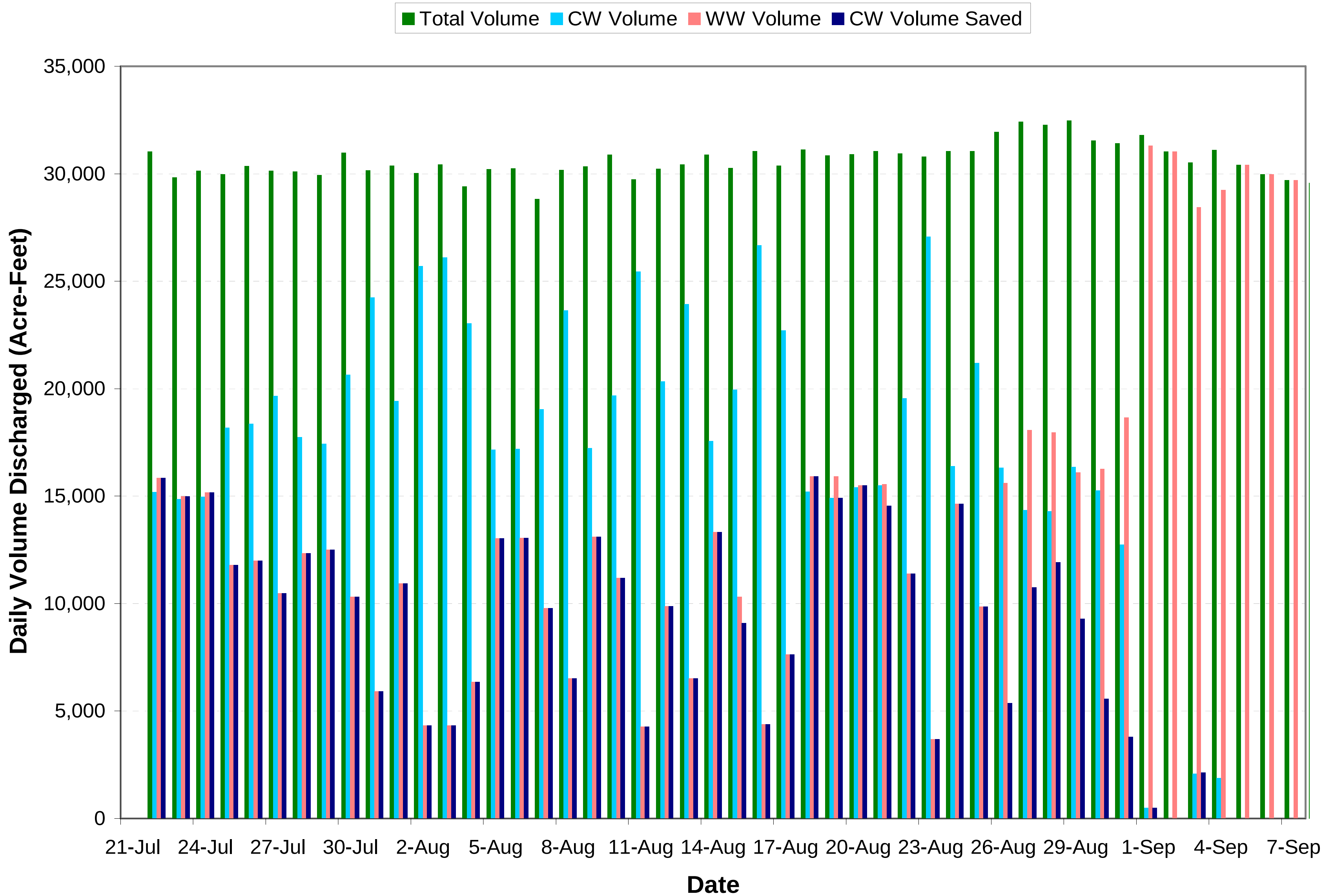


Plate 31. Potential savings of optimal coldwater habitat in Garrison Reservoir over the period July 22, to September 7, 2005 due to implementation of short-term water quality management measures at Garrison Dam. (Note: No water meeting optimal coldwater habitat criteria was discharged through Garrison Dam from September 8, to September 30, 2005, based on monitoring of dynamic water quality conditions in the five penstocks. Optimal Coldwater Habitat is defined as water that is ≤15°C and ≥ 5 mg/l dissolved oxygen.)

Plate 32. Summary of water quality conditions monitored in Oahe Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	23	1582.3	1576.9	1572.3	1608 5	-----	-----	-----
Water Temperature (C)	0.1	873	12.9	11.4	4.7	24 2	18.3	180	21%
Dissolved Oxygen (mg/l)	0.1	873	8.9	8.7	5.7	12.7	≥ 6.0 ≥ 7.0	2 53	<1% 6%
Dissolved Oxygen (% Sat.)	0.1	873	87.7	90.5	49.4	107.4	-----	-----	-----
Specific Conductance (umho/cm)	1	873	686	704	534	861	-----	-----	-----
pH (S.U.)	0.1	784	8.2	8.2	7.3	9 3	≥6.6 & ≤8.6	150	19%
Turbidity (NTUs)	0.1	596	8.6	5.0	n.d.	44.2	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	599	367	367	292	465	-----	-----	-----
Secchi Depth (in.)	1	22	159	157	70	256	-----	-----	-----
Alkalinity, Total (mg/l)	7	50	179	180	153	209	-----	-----	-----
Ammonia, Total (mg/l)	0.01	41	-----	0.08	n.d.	0.47	3.8 [(1,2)], 0.58 [(1,3)]	0	0%
Carbon, Total Organic (mg/l)	0.05	47	3.3	3.1	2.8	4.6	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	424	-----	n.d.	n.d.	7	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	18	-----	n.d.	n.d.	8	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	17	517	490	410	685	1,750[(5)]	0	0%
Hardness, Total (mg/l)	0.4	17	242	241	221	260	-----	-----	-----
Iron, Dissolved (ug/l)	40	8	-----	n.d.	n.d.	n.d.	-----	-----	-----
Iron, Total (ug/l)	40	12	-----	n.d.	n.d.	207	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	51	-----	0.26	n.d.	0.7	-----	-----	-----
Manganese, Dissolved (ug/l)	1	8	14	5	n.d.	49	-----	-----	-----
Manganese, Total (ug/l)	1	12	-----	7	n.d.	75	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	49	-----	n.d.	n.d.	0.46	10[(5)]	0	0%
Phosphorus, Dissolved (mg/l)	0.01	12	-----	0.03	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	51	-----	0.03	n.d.	0.20	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	48	-----	n.d.	n.d.	0.01	-----	-----	-----
Silica, Total (ug/l)	20	7	2,513	2,326	2,125	3,045	-----	-----	-----
Sulfate (mg/l)	0.1	14	202	200	194	210	875[(5)]	0	0%
Suspended Solids, Total (mg/l)	4	51	-----	n.d.	n.d.	8	53[(2)], 30[(3)]	0	0%
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	6[(4)]	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	3.2	340[(2)], 150[(3)], 0.018[(4)]	0/0/b.d.	0%/0%/b.d.
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	4[(4)]	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	9.6[(2)], 2.0[(3)]	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	34	1,128[(2)], 366[(3)]	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	39.0[(2)], 24 1[(3)], 1,300[(4)]	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	165[(2)], 6.5[(3)]	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.4[(2)]	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	0.02	0.012[(3)]	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	2,979[(2)], 331[(3)], 610[(4)]	0	0%
Selenium, Total (ug/l)	4	4	-----	n.d.	n.d.	n.d.	4.6[(3)], 170[(4)]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	15.7[(2)]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Total (ug/l)	3	4	-----	4.4	n.d.	5.8	241[(2)], 220[(3)] 7,400[(4)]	0	0%
Alachlor, Total (ug/l)	0.05	15	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)	0.05	15	-----	n.d.	n.d.	0.46	-----	-----	-----
Metolachlor, Total (ug/l)	0.05	15	-----	n.d.	n.d.	n.d.	-----	-----	-----
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.	n.d.	n.d.	****	0	0%
Microcystins, Total (ug/l)	0.2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [(1)]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.2 and 11.4 respectively.
[(2)] Acute criterion for aquatic life.
[(3)] Chronic criterion for aquatic life.
[(4)] Human health criterion for surface waters.
[(5)] Daily maximum criterion for domestic water supply.
Note: Many South Dakota's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 241 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 33. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division, and dominant taxa present for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site at Oahe Reservoir during the period 2004 through 2005.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	7,414,456	2	0 19	0	-----	0	-----	1	0.14	4	0.37	1	0.30	0	-----	1.48
Jul 2004	4,313,125	2	0.14	0	-----	0	-----	2	0.75	3	0.11	0	-----	0	-----	1.25
Aug 2004	164,005,921	4	0.78	0	-----	1	0.07	1	0.02	3	<0.01	1	0.14	0	-----	0.85
Sep 2004	5,604,589	2	0.38	1	0.04	0	-----	1	0.03	3	0.35	0	-----	1	0.20	1.45
May 2005	185,149,541	3	0.96	2	0.01	1	<0.01	1	0.03	0	-----	0	-----	0	-----	0.96
Jun 2005	55,201,496	4	0.58	1	0.8	0	-----	1	0.11	3	0.02	1	0.22	0	-----	1.78
Jul 2005	45,943,019	4	0.31	2	0.04	1	0.35	1	0.04	3	0.02	1	0.25	0	-----	1.73
Aug 2005	37,779,368	5	0.84	1	0.12	0	-----	0	-----	3	0.04	0	-----	0	-----	1.58
Sep 2005	100,194,654	9	0.46	7	0.09	2	0.14	2	0.04	4	0.22	1	0.05	0	-----	2.39
Mean*	**67,289,574**	**3.9**	**0.52**	**1.6**	**0.18**	**0.6**	**0.14**	**1.1**	**0.15**	**2.9**	**0.14**	**0.6**	**0.19**	**0.1**	**0.20**	**1.50**

* Mean percent composition represents the mean when taxa of that division are present.

Date	Division	Dominant Taxa*	Percent of Total Biovolume	Date	Division	Dominant Taxa	Percent of Total Biovolume
				May 2005	Bacillariophyta	*Asterionella formossa*	0.60
					Bacillariophyta	*Fragilaria construens*	0.33
June 2004	Cyanobacteria	*Anabaena spp.*	0.34	June 2005	Bacillariophyta	*Stephanodiscus spp.*	0.29
	Pyrrophyta	*Peridinium inconspicuum*	0.30		Pyrrophyta	*Peridinium spp.*	0.22
	Bacillariophyta	*Fragilaria construens*	0.17		Bacillariophyta	*Fragilaria crotonensis*	0.14
	Cryptophyta	*Rhodomonas minuta*	0.14		Bacillariophyta	*Asterionella formossa*	0.14
					Cryptophyta	*Cryptomonas spp.*	0.11
July 2004	Cryptophyta	*Rhodomonas minuta*	0.59	July 2005	Chrysophyta	*Dinobryon sertularia*	0.35
	Cryptophyta	*Cryptomonas spp.*	0.16		Pyrrophyta	*Ceratium hirundinella*	0.25
	Bacillariophyta	*Asterionella formossa*	0.12		Bacillariophyta	*Stephanodiscus hantzschii*	0.20
August 2004	Bacillariophyta	*Fragilaria crotonensis*	0.75	August 2005	Bacillariophyta	*Asterionella formossa*	0.41
	Pyrrophyta	*Ceratium hirundinella*	0.13		Bacillariophyta	*Synedra spp.*	0.23
					Bacillariophyta	*Navicula spp.*	0.14
					Chlorophyta	*Chlamydomonas spp.*	0.12
September 2004	Bacillariophyta	*Aulacoseira islandica*	0.25	September 2005	Bacillariophyta	*Aulacoseira granulata*	0.22
	Cyanobacteria	*Anabaena circinalis*	0.23		Cyanobacteria	*Anabaena spp.*	0.18
	Bacillariophyta	*Cyclotella spp.*	0.13		Chrysophyta	*Dinobryon sertularia*	0.13
	Cyanobacteria	*Anabaena flos-aquae*	0.11				

* Dominant taxa are genera or species (depending on identification level) that comprised more than 10% of the total sample biovolume.

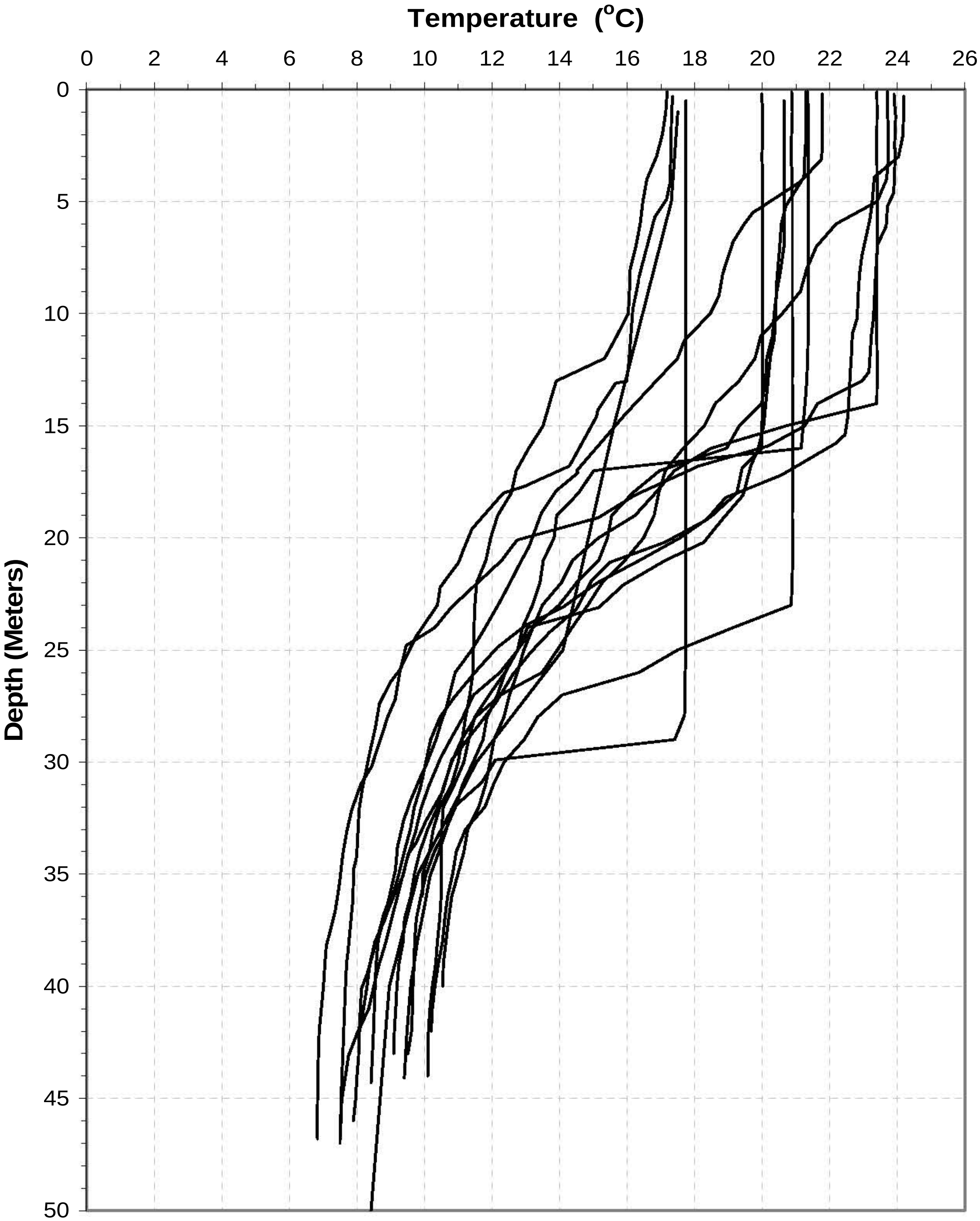


Plate 34. Temperature depth profiles for Oahe Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005.

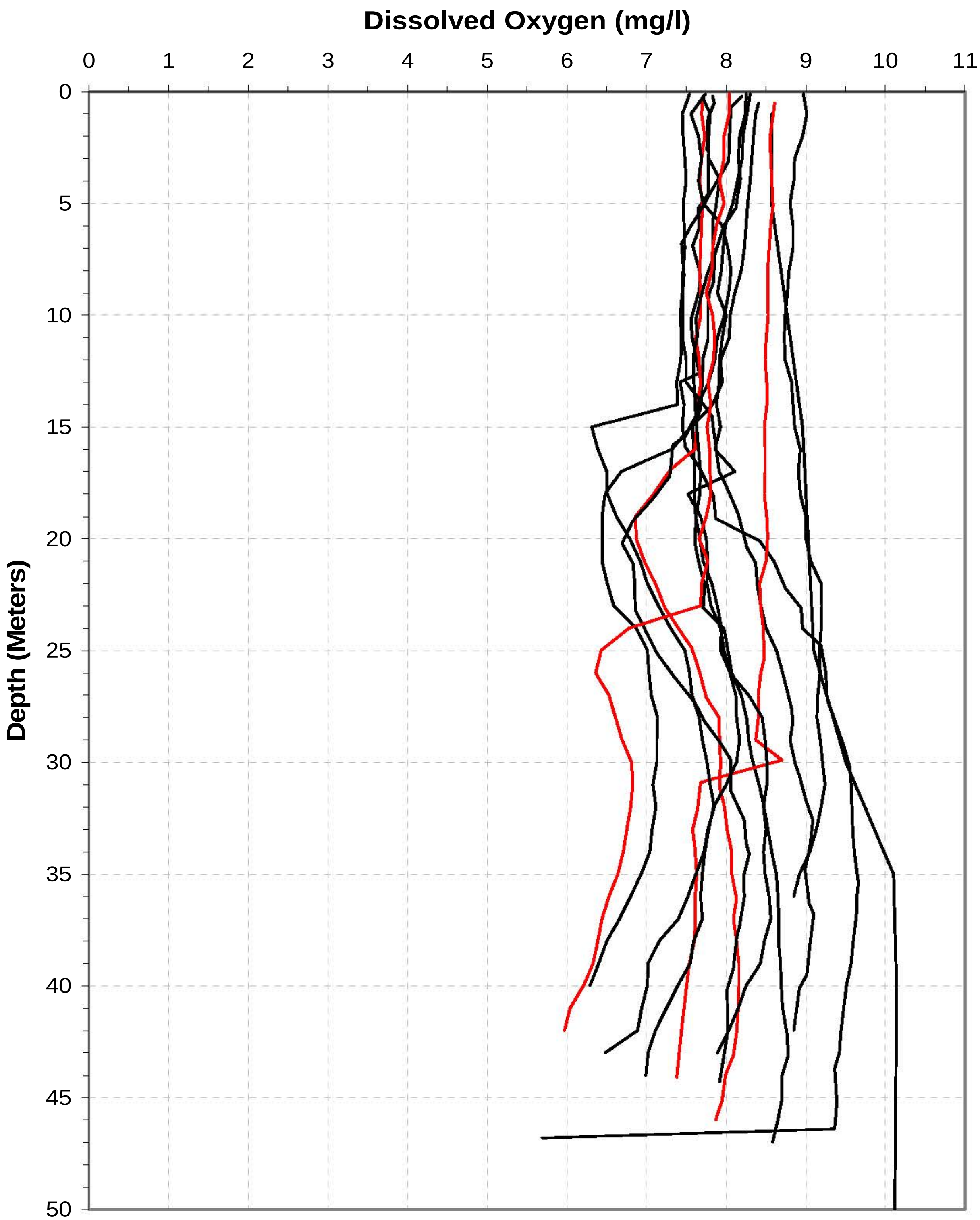


Plate 35. Dissolved oxygen depth profiles for Oahe Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July through September over the 5-year period of 2001 to 2005. (Note: Red profiles were measured in the month of September.)

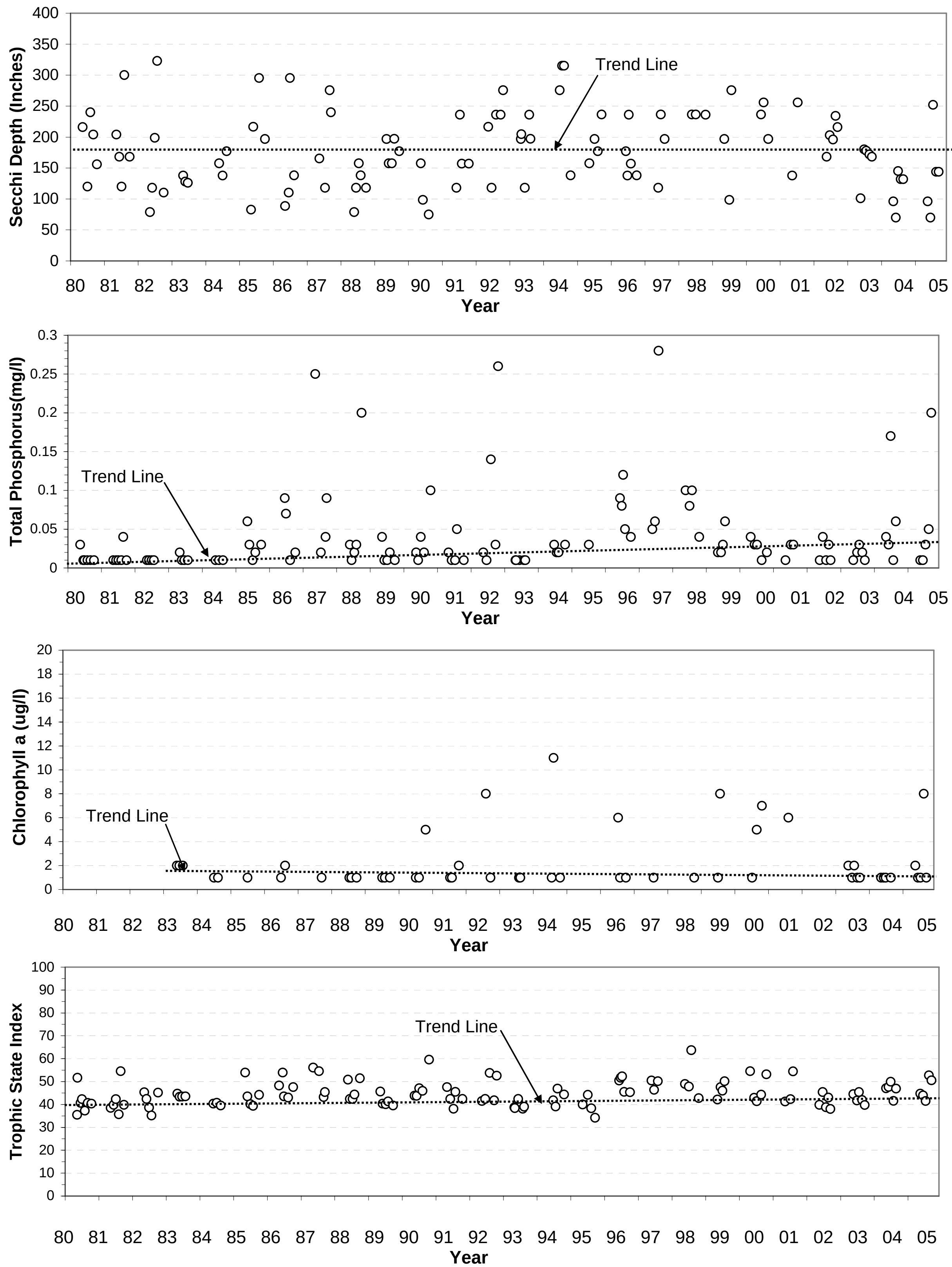


Plate 36. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Oahe Reservoir at the near-dam, ambient site over the 26-year period of 1980 to 2005.

Plate 37. Summary of water quality conditions monitored on water discharged through Oahe Dam during the 1-year period of October 1, 2004 through September 30, 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Dam Discharge (cfs)	1	8,759	14,945	13,070	0	52,310	-----	-----	-----
Water Temperature (C)	0.1	7,247	11.8	12.1	1.5	24.3	18.3	2,182	30%
Dissolved Oxygen (mg/l)	0.1	6,432	9.0	8.9	4.9	14.8	≥ 7.0 ≥ 6.0	1,875 1,193	29% 19%
Dissolved Oxygen (% Sat.)	0.1	6,432	86.8	89.3	55.4	119.4	-----	-----	-----
Specific Conductance (umho/cm)	1	6,529	611	642	377	874	-----	-----	-----
pH (S.U.)	0.1	6,629	8.6	8.6	8.0	9.0	≥6.6 & ≤8.6	2,837	43%
Alkalinity, Total (mg/l)	7	11	175	178	160	181	-----	-----	-----
Ammonia, Total (mg/l)	0.01	11	-----	0.07	n.d.	0.23	1.8 [1,2], 0.8 [1,3]	0	0%
Carbon, Total Organic (mg/l)	0.05	11	3.0	2.9	2.9	3.5	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	11	461	450	404	615	1,750[5]	0	0%
Hardness, Total (mg/l)	0.4	3	220	224	214	224	-----	-----	-----
Iron, Dissolved (ug/l)	40	11	-----	n.d.	n.d.	50	-----	-----	-----
Iron, Total (ug/l)	40	11	69	50	n.d.	157	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	11	0.4	0.3	0.2	1.0	-----	-----	-----
Manganese, Dissolved (ug/l)	1	11	-----	n.d.	n.d.	8	-----	-----	-----
Manganese, Total (ug/l)	1	11	13	11	5	29	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	11	-----	n.d.	n.d.	n.d.	10[5]	0	0%
Phosphorus, Dissolved (mg/l)	0.01	3	0.03	0.03	0.02	0.03	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	11	0.03	0.04	n.d.	0.06	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	11	-----	n.d.	n.d.	n.d.	-----	-----	-----
Sulfate (mg/l)	0.1	11	205	201	194	230	875[5]	0	0%
Suspended Solids, Total (mg/l)	4	11	-----	n.d.	n.d.	44	53[2], 30[3]	0	0%
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6[4]	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	340[2], 150[3], 0.018[4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4[4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	8.9[2], 1.9[3]	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,062[2], 345[3]	0	0%
Copper, Dissolved (ug/l)	2	3	3	2	2	6	36.4[2], 22.6[3], 1,300[4]	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	153[2], 6.0[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	0.012[3]	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	2,800[2], 311[3], 610[4]	0	0%
Selenium, Total (ug/l)	4	3	-----	n.d.	n.d.	n.d.	4.6[3], 170[4]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	13.8[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	3	n.d.	4	227[2], 207[3], 7,400[4]	0	0%
Pesticide Scan (ug/l)***	0.05	1	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.6 and 12.1 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many South Dakota's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 224 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

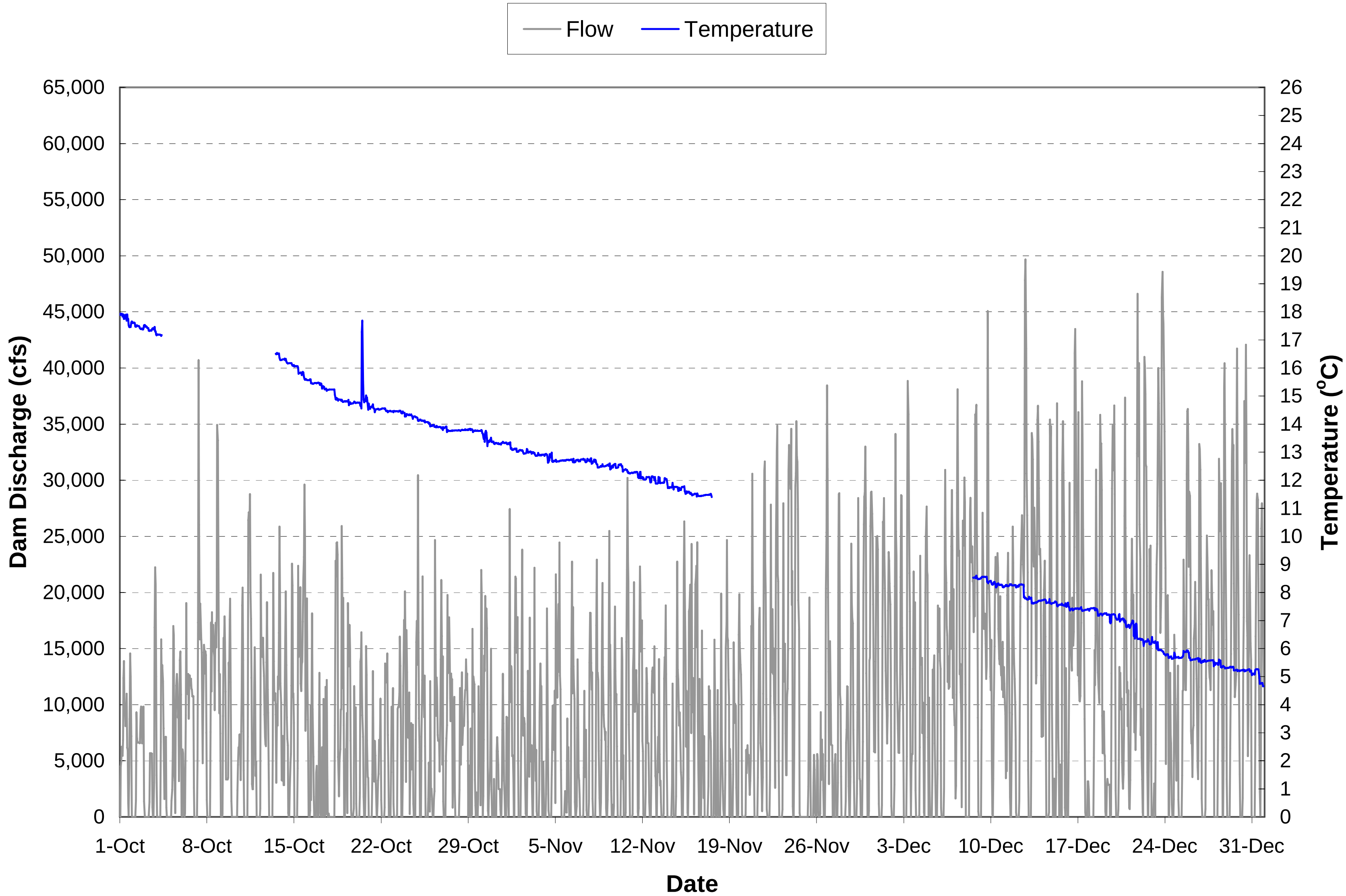


Plate 38. Hourly discharge and water temperature monitored at the Oahe power plant on water discharged through the dam during the period October through December 2004. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

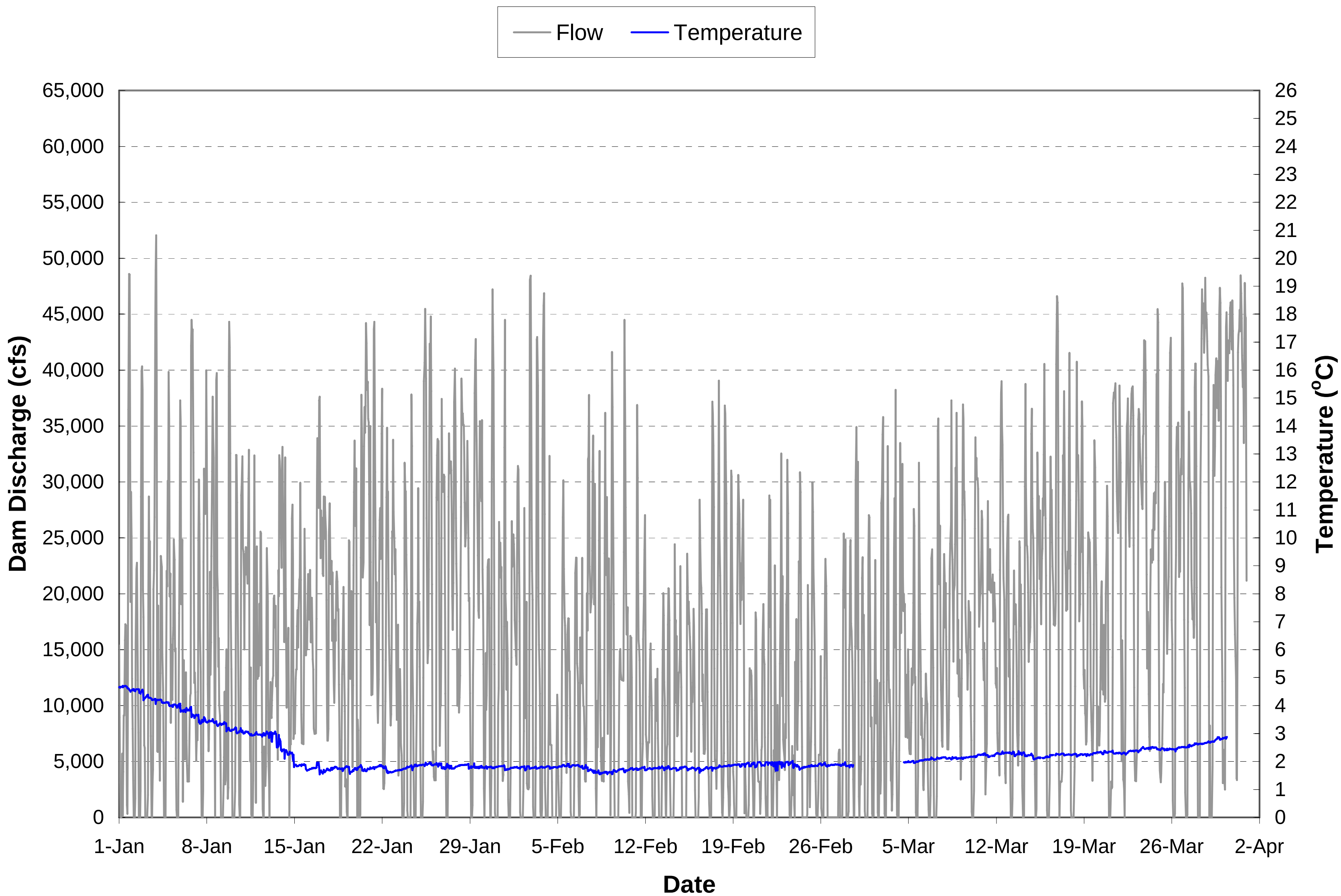


Plate 39. Hourly discharge and water temperature monitored at the Oahe power plant on water discharged through the dam during the period January through March 2005. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

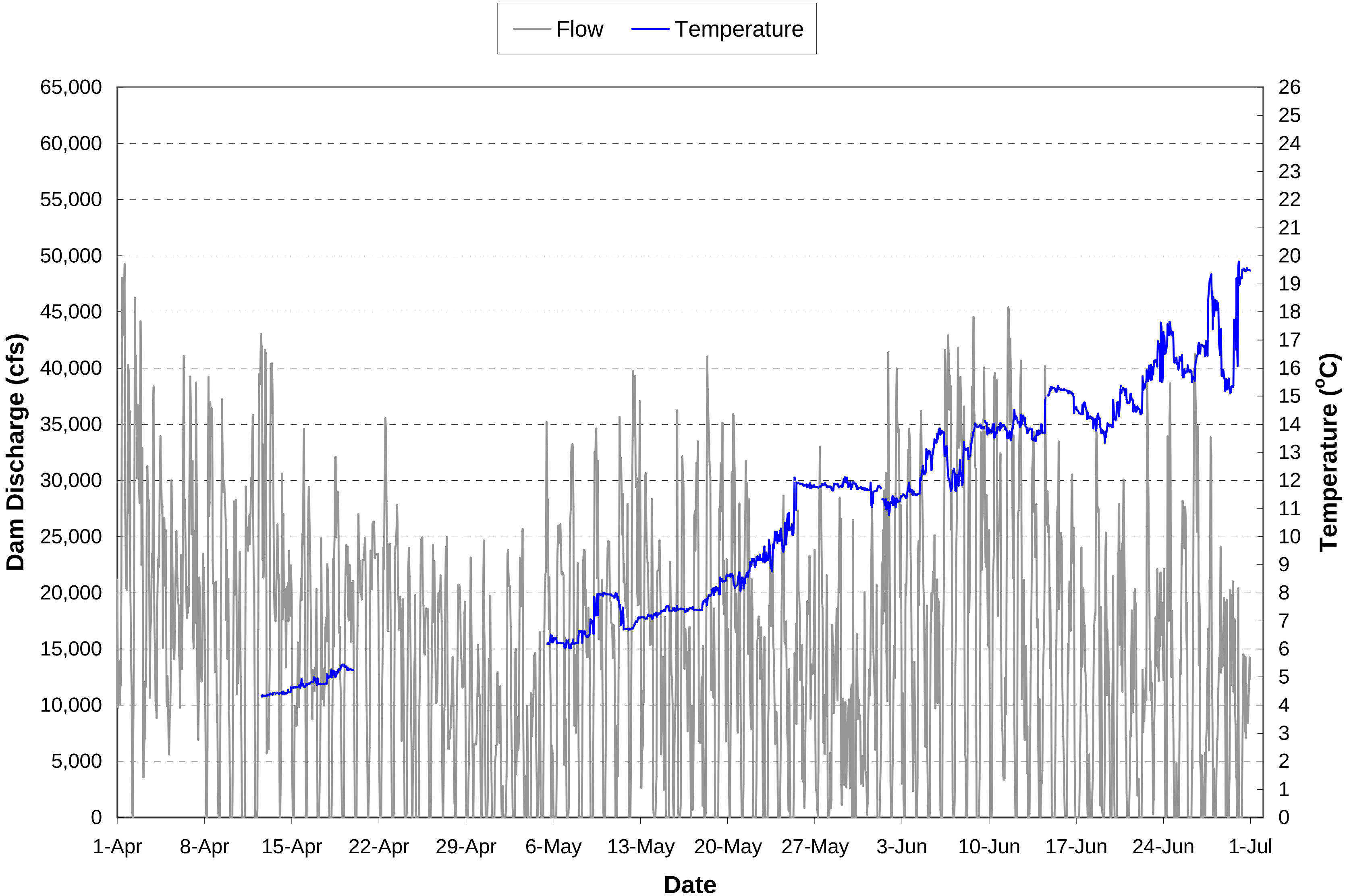


Plate 40. Hourly discharge and water temperature monitored at the Oahe power plant on water discharged through the dam during the period April through June 2005. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

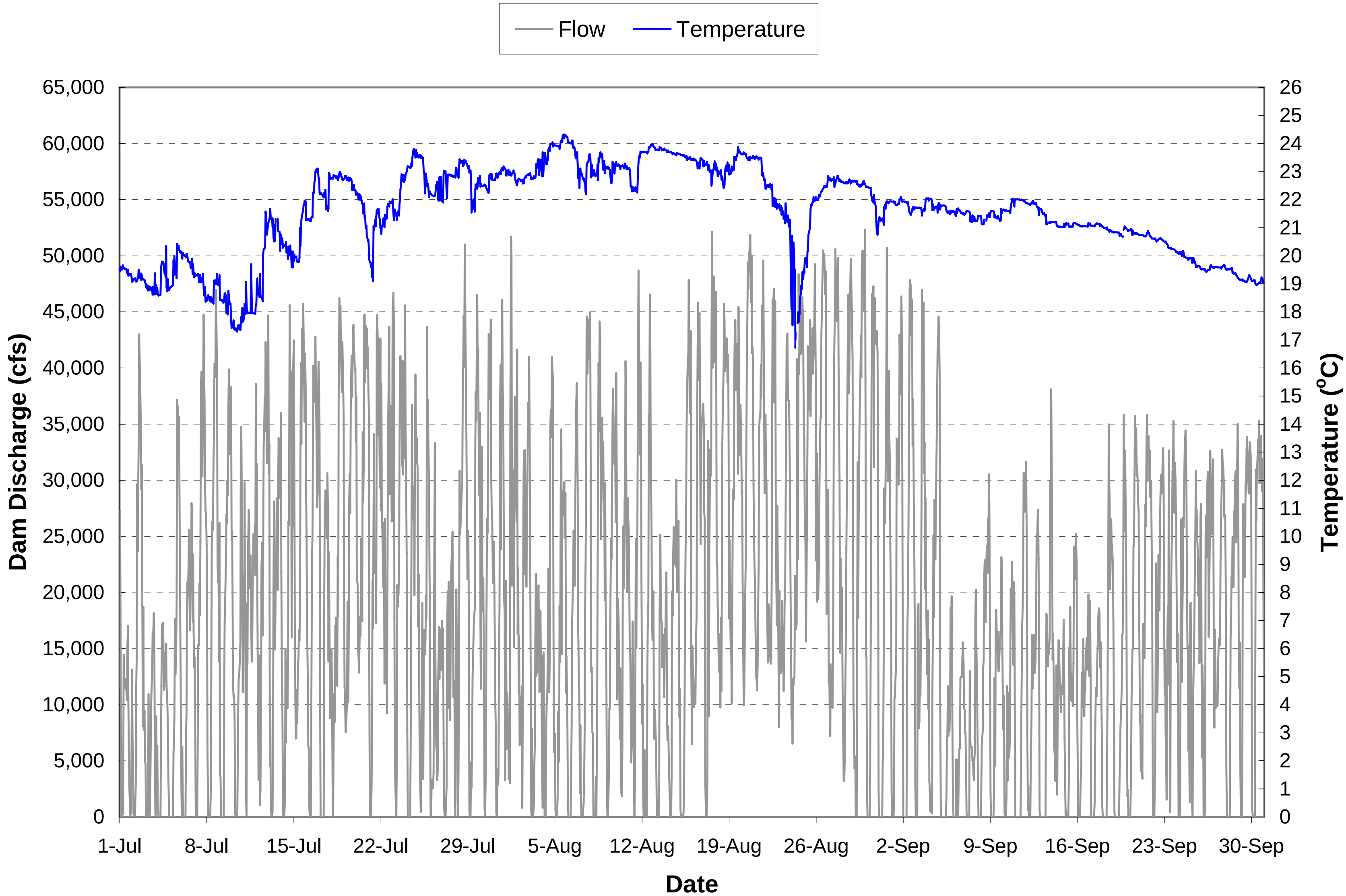


Plate 41. Hourly discharge and water temperature monitored at the Oahe power plant on water discharged through the dam during the period July through September 2005.

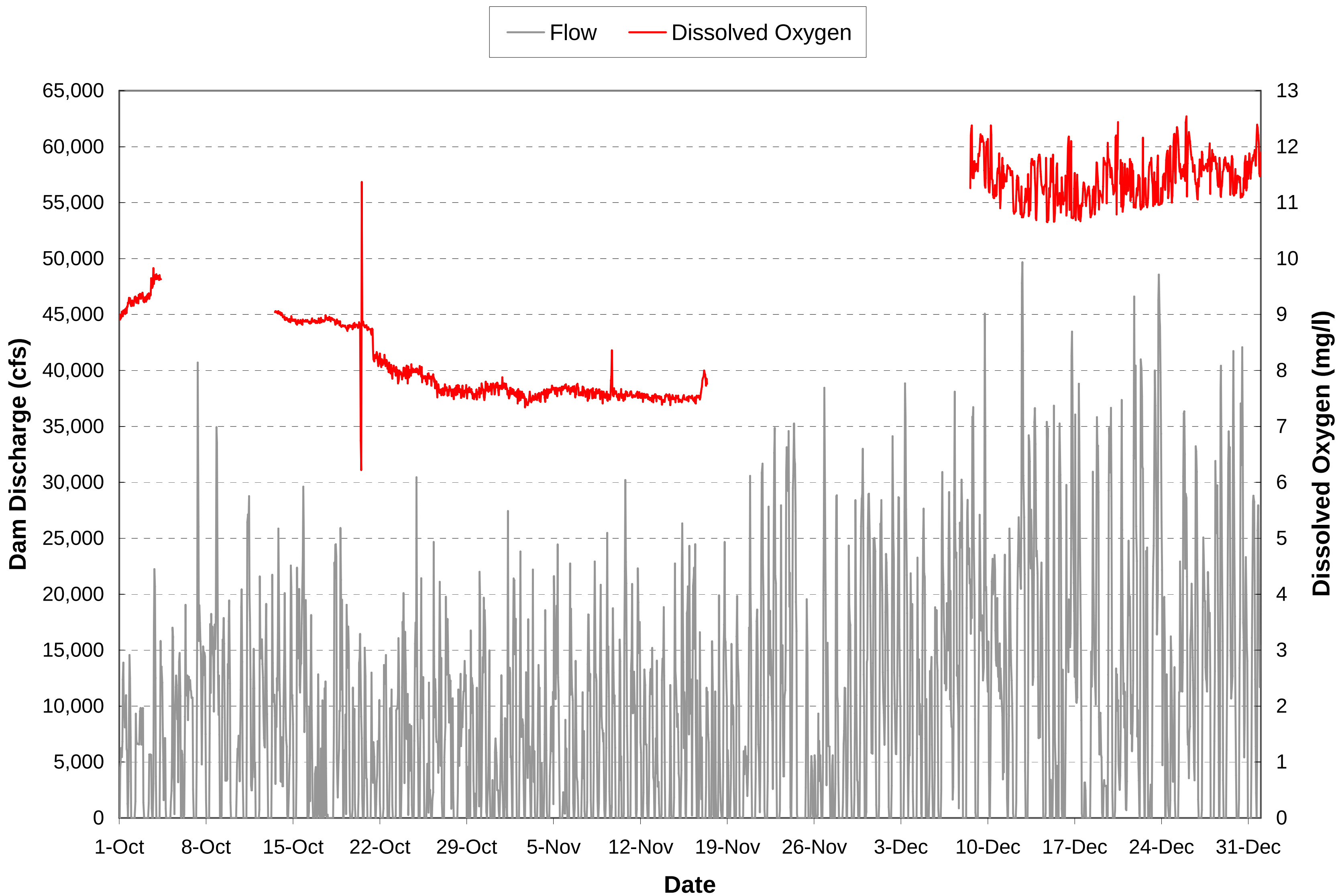


Plate 42. Hourly discharge and dissolved oxygen concentrations monitored at the Oahe power plant on water discharged through the dam during the period October through December 2004. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

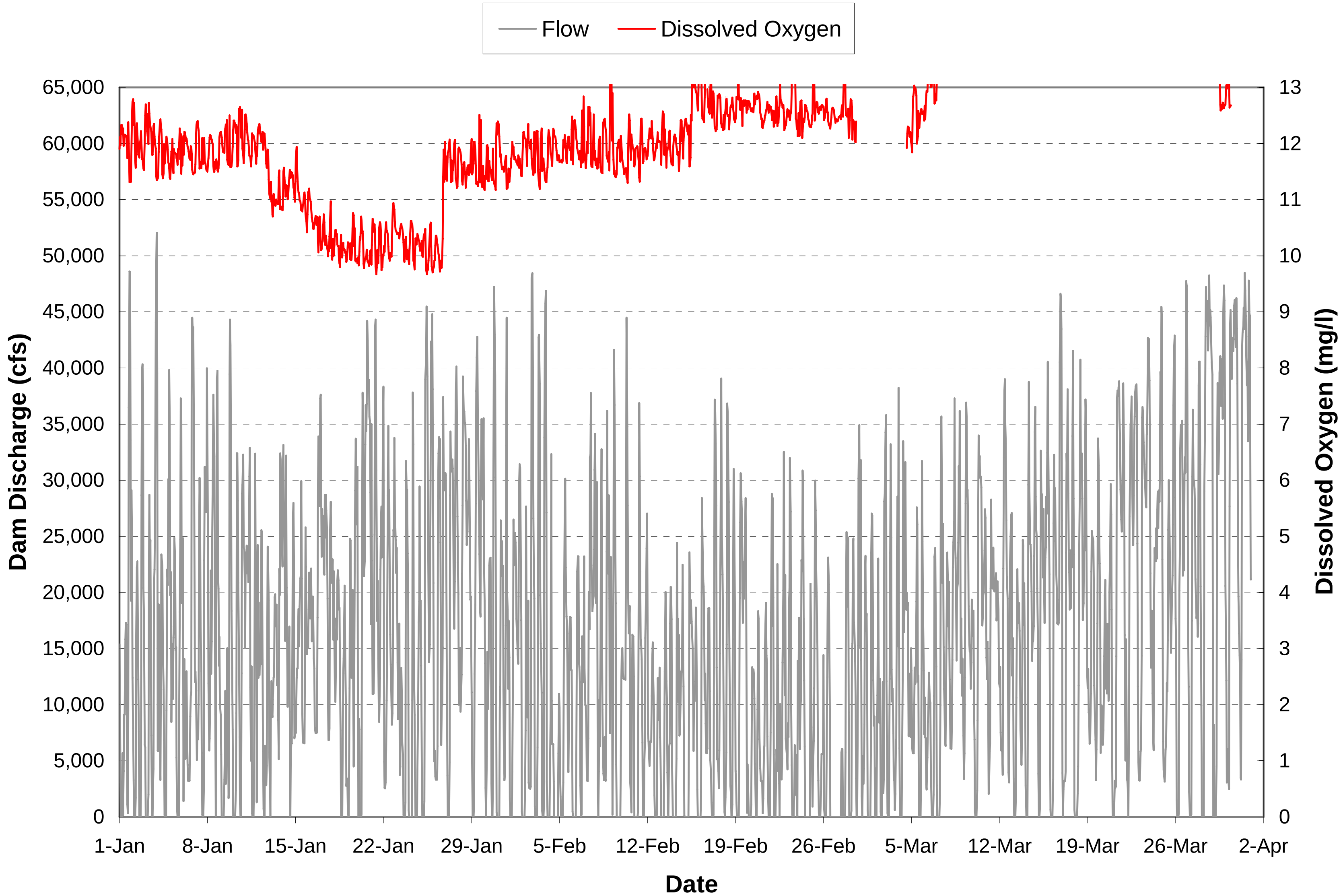


Plate 43. Hourly discharge and dissolved oxygen concentrations monitored at the Oahe power plant on water discharged through the dam during the period January through March 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

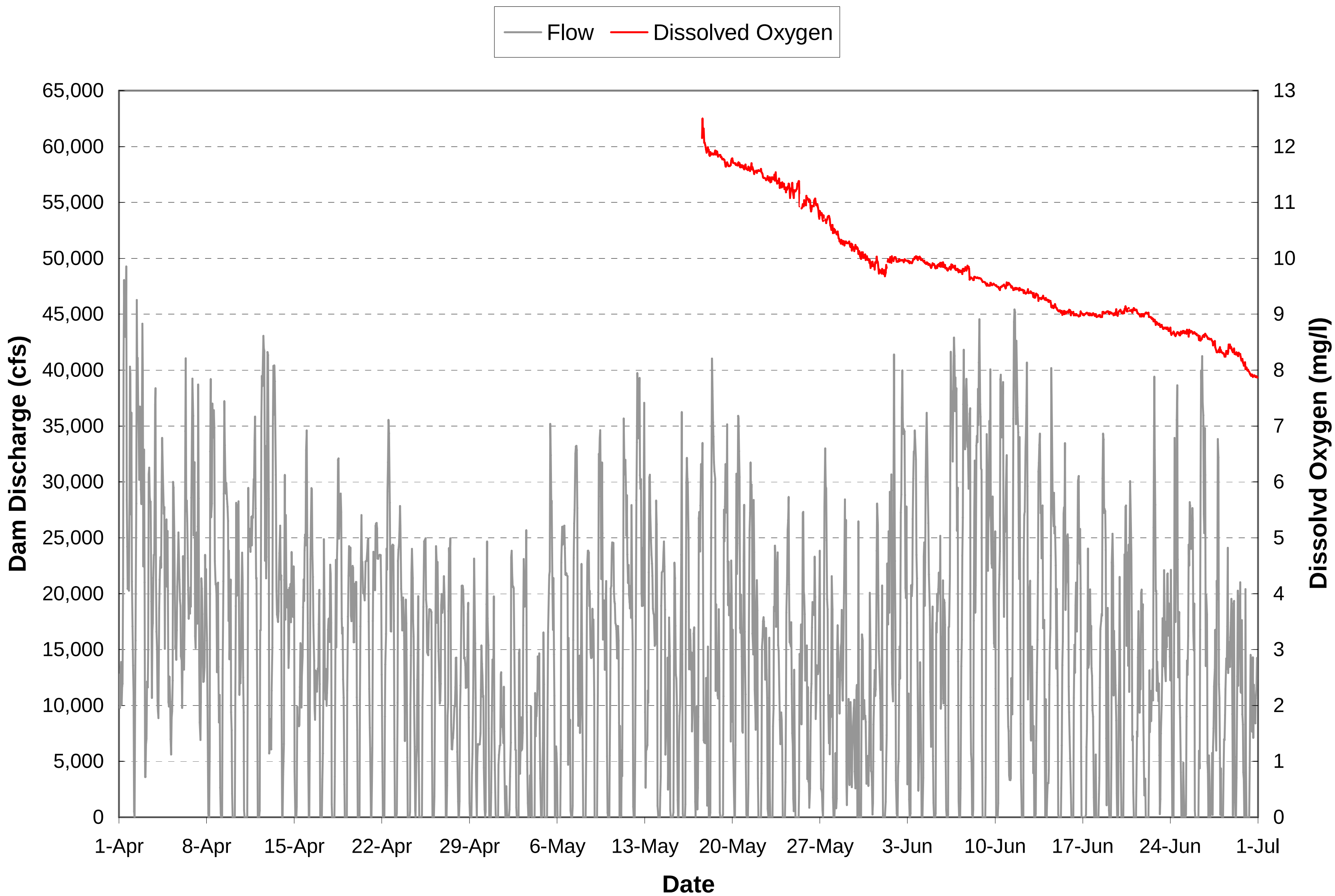


Plate 44. Hourly discharge and dissolved oxygen concentrations monitored at the Oahe power plant on water discharged through the dam during the period April through June 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

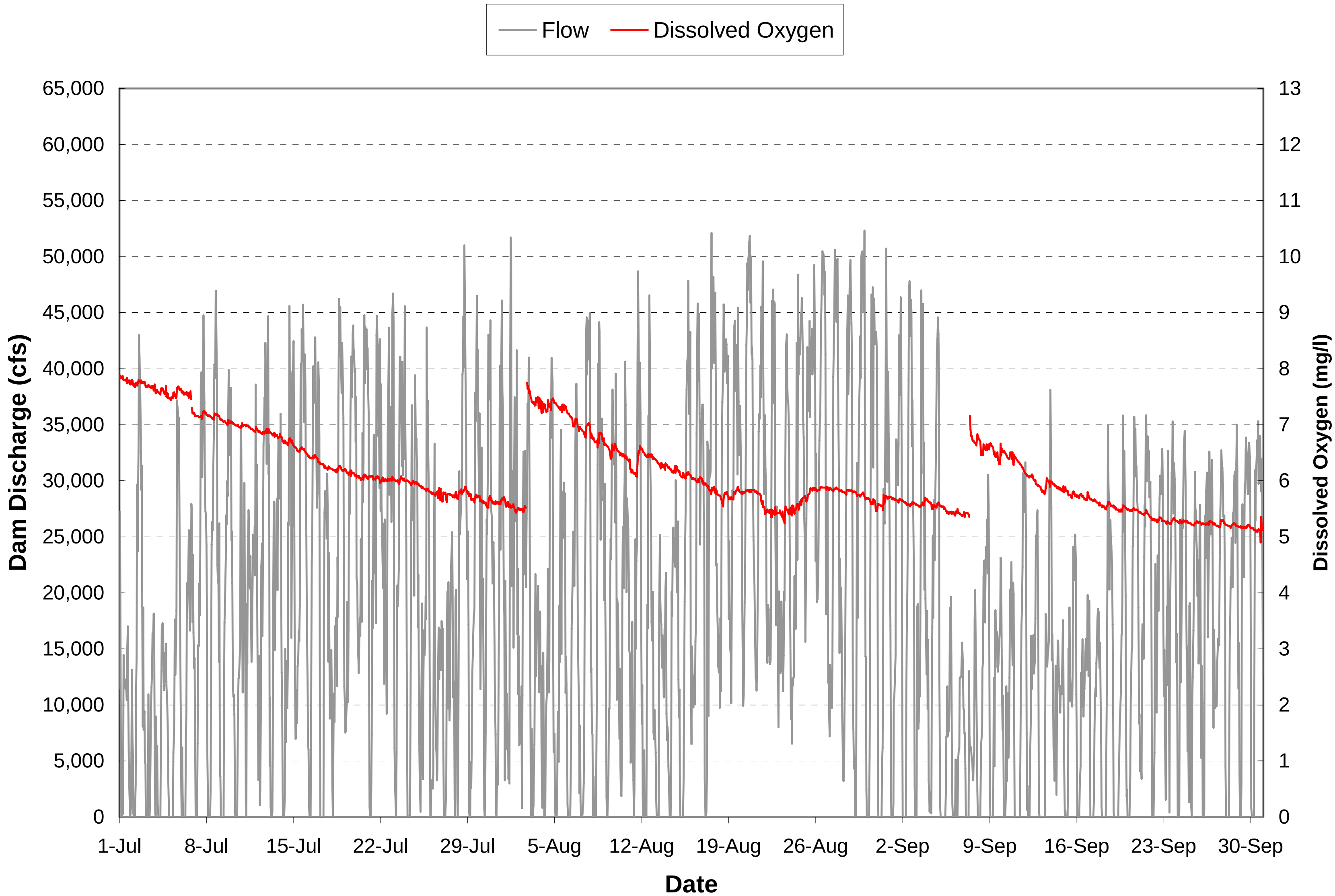


Plate 45. Hourly discharge and dissolved oxygen concentrations monitored at the Oahe power plant on water discharged through the dam during the period July through September 2005. (Note gaps in dissolved oxygen plot represents significant calibration concerns and probable measurement error.)

Plate 46. Summary of water quality conditions monitored in Big Bend Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	23	1420.2	1420.3	1417.7	1420.9	-----	-----	-----
Water Temperature (C)	0.1	480	19.3	19.5	10.3	27.3	18.3	319	66%
Dissolved Oxygen (mg/l)	0.1	480	7.9	7.7	3.1	10.4	≥ 6.0 ≥ 7.0	18 92	4% 19%
Dissolved Oxygen (% Sat.)	0.1	480	89.5	90.8	37.3	107.7	-----	-----	-----
Specific Conductance (umho/cm)	1	480	703	170	546	801	-----	-----	-----
pH (S.U.)	0.1	457	8.3	8.3	7.8	9.0	≥6.6 & ≤8.6	64	14%
Turbidity (NTUs)	0.1	315	6.6	5.1	n.d.	34.9	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	318	369	379	259	411	-----	-----	-----
Secchi Depth (in.)	1	20	85	80	40	196	-----	-----	-----
Alkalinity, Total (mg/l)	7	42	176	176	146	198	-----	-----	-----
Ammonia, Total (mg/l)	0.01	33	-----	0.09	n.d.	0.48	3.15 [1,2], 1.06 [1,3]	0	0%
Carbon, Total Organic (mg/l)	0.05	39	3.3	3.1	2.9	5.4	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	227	-----	n.d.	n.d.	14	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	16	-----	1	n.d.	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	9	541	510	460	709	1,750[5]	0	0%
Hardness, Total (mg/l)	0.4	12	252	240	218	401	-----	-----	-----
Iron, Dissolved (ug/l)	40	1	-----	n.d.	n.d.	n.d.	-----	-----	-----
Iron, Total (ug/l)	40	3	130	128	122	142	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	43	-----	0.2	n.d.	0.8	-----	-----	-----
Manganese, Dissolved (ug/l)	1	1	5	5	5	5	-----	-----	-----
Manganese, Total (ug/l)	1	3	23	26	15	28	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	41	-----	n.d.	n.d.	0.30	10[5]	0	0%
Phosphorus, Total (mg/l)	0.01	43	0.04	0.02	n.d.	0.47	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	43	-----	n.d.	n.d.	0.04	-----	-----	-----
Silica, Total (ug/l)	20	1	1,579	1,579	1,579	1,579	-----	-----	-----
Sulfate (mg/l)	0.1	8	218	220	200	248	875[5]	0	0%
Suspended Solids, Total (mg/l)	4	43	-----	n.d.	n.d.	9.5	53[2], 30[3]	0	0%
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	6[4]	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	3.6	340[2], 150[3], 0.018[4]	0/0/b.d.	0%/0%/b.d.
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	4[4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	9.6[2], 2.0[3]	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	1,128[2], 366[3]	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	39.0[2], 24.1[3], 1,300[4]	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	165[2], 6.5[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	5	-----	n.d.	n.d.	0.09	0.012[3]	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	2,979[2], 331[3], 610[4]	0	0%
Selenium, Total (ug/l)	4	4	-----	n.d.	n.d.	n.d.	4.6[3], 170[4]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	15.7[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Total (ug/l)	3	2	5.6	5.6	4.5	6.7	241[2], 220[3] 7,400[4]	0	0%
Alachlor, Total (ug/l)	0.05	15	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)	0.05	15	-----	n.d.	n.d.	0.08	-----	-----	-----
Metolachlor, Total (ug/l)	0.05	15	-----	n.d.	n.d.	n.d.	-----	-----	-----
Pesticide Scan (ug/l)***	0.05	5	-----	n.d.	n.d.	n.d.	****	0	0%
Microcystins, Total (ug/l)	0.2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 3 and 19.5 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many South Dakota's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 240 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 47. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division, and dominant taxa present for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site at Big Bend Reservoir during the period 2004 through 2005.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	6,563,514	3	0.77	0	-----	0	-----	2	0.20	2	0.04	0	-----	0	-----	1.24
Jul 2004	6,337,657	1	0.77	0	-----	0	-----	1	0.03	4	0.20	0	-----	0	-----	0.70
Aug 2004	129,629,728	7	0.79	5	0.05	0	-----	1	0.02	3	<0.01	2	0.13	0	-----	1.15
May 2005	400,458,770	6	0.93	3	<0.01	0	-----	1	0.07	1	<0.01	0	-----	0	-----	1.47
Jun 2005	12,306,159	2	0 26	1	0.04	0	-----	2	0.63	4	0.07	0	-----	0	-----	1.58
Jul 2005	223,854,976	11	0 97	2	0.01	0	-----	0	-----	1	0.01	0	-----	0	-----	1.55
Aug 2005	111,016,029	5	0.22	0	-----	2	0.26	1	0.03	8	0.48	0	-----	0	-----	2.03
Sep 2005	290,622,396	8	0.77	14	0.06	0	-----	1	0.04	5	0.12	2	<0.01	1	<0.01	1.80
Mean	**147,598,654**	**5.4**	**0.69**	**3.1**	**0.03**	**0.3**	**0.26**	**1.1**	**0.15**	**3.5**	**0.12**	**0.5**	**0.07**	**0.1**	**<0.01**	**1.44**

* Mean percent composition represents the mean when taxa of that division are present.

Date	Division	Dominant Taxa*	Percent of Total Biovolume	Date	Division	Dominant Taxa	Percent of Total Biovolume
				May 2005	Bacillariophyta	*Fragilaria crotonensis*	0.36
					Bacillariophyta	*Tabellaria fenestrata*	0.29
					Bacillariophyta	*Asterionella formossa*	0.23
June 2004	Bacillariophyta	*Asterionella formossa*	0.61	June 2005	Cryptophyta	*Rhodomonas minuta*	0.37
	Bacillariophyta	*Navicula spp.*	0.14		Cryptophyta	*Cryptomonas spp.*	0.26
	Cryptophyta	*Rhodomonas minuta*	0.13		Bacillariophyta	*Stephanodiscus spp.*	0.22
July 2004	Bacillariophyta	*Asterionella formossa*	0.77	July 2005	Bacillariophyta	*Fragilaria crotonensis*	0.45
	Cyanobacteria	*Anabaena spp.*	0.13		Bacillariophyta	*Asterionella formossa*	0.31
August 2004	Bacillariophyta	*Fragilaria crotonensis*	0.70	August 2005	Cyanobacteria	*Pseudanabaena limnetica*	0.33
	Pyrrophyta	*Ceratium hirundinella*	0.13		Chrysophyta	*Dinobryon sertularia*	0.24
				September 2005	Bacillariophyta	*Stephanodiscus hantzschii*	0.56

* Dominant taxa are genera or species (depending on identification level) that comprised more than 10% of the total sample biovolume.

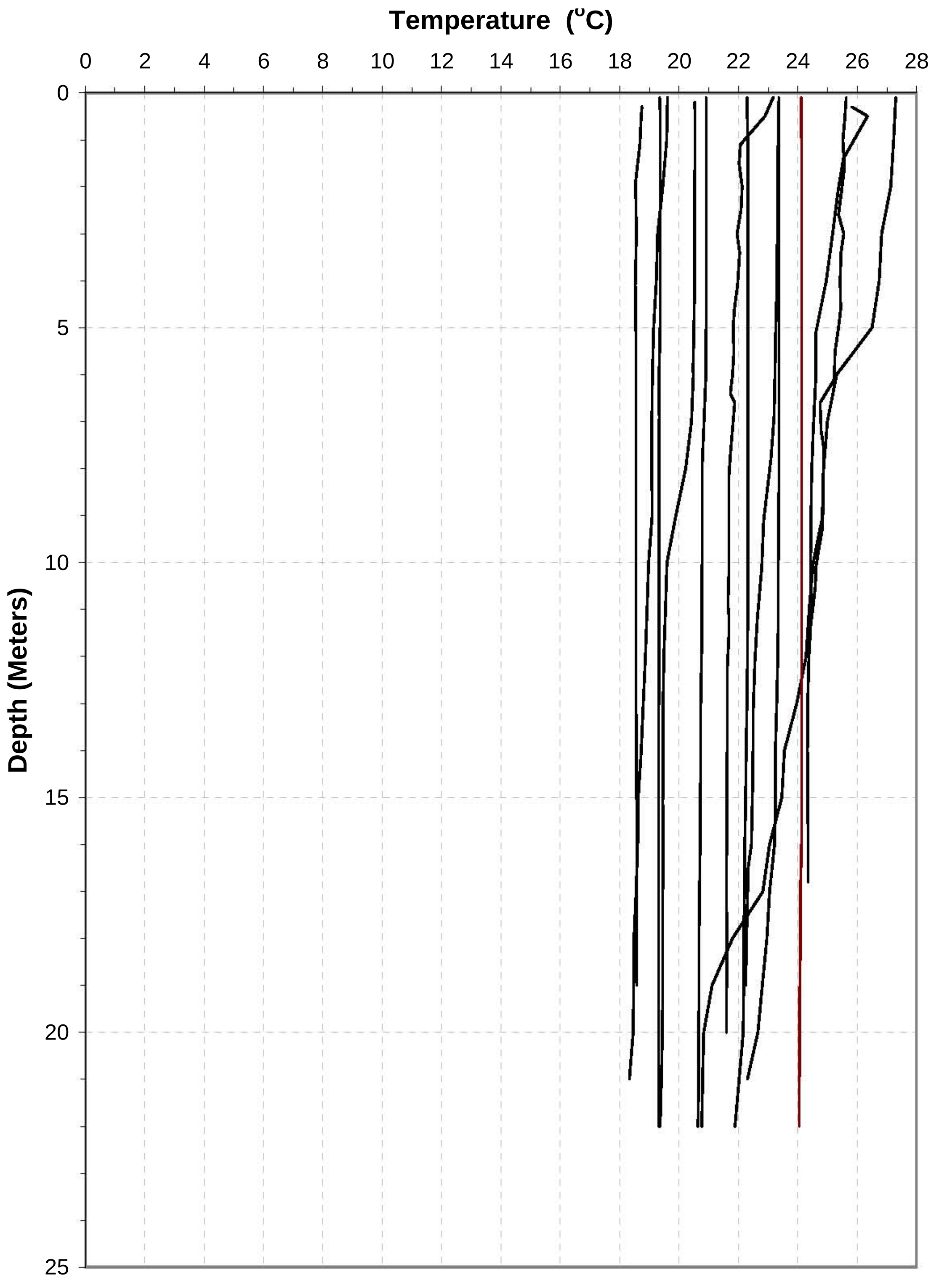


Plate 48. Temperature depth profiles for Big Bend Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005.

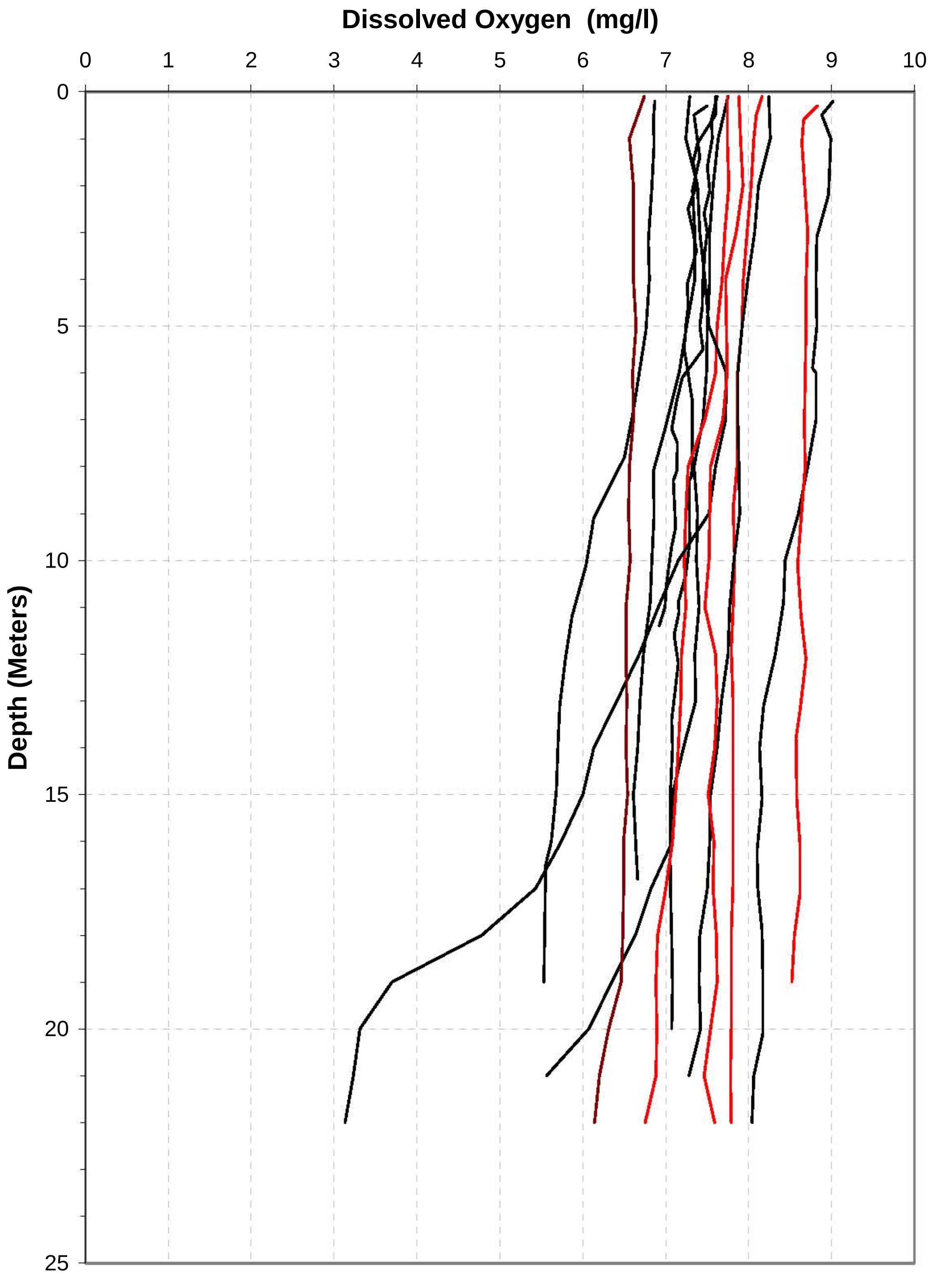


Plate 49. Dissolved oxygen depth profiles for Big Bend Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005. (Note: Red profiles were measured in the month of September.)

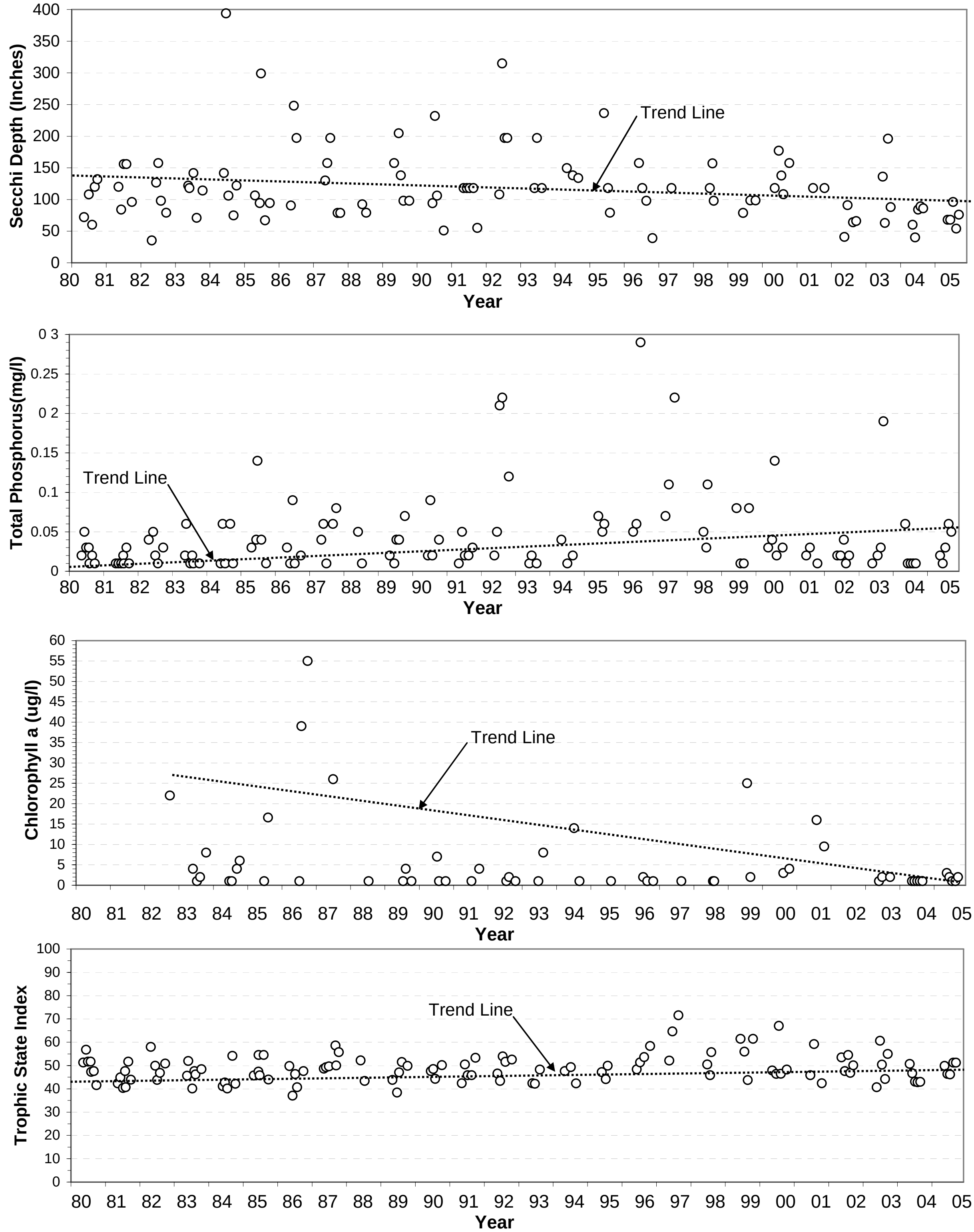


Plate 50. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Big Bend Reservoir at the near-dam, ambient site over the 26-year period of 1980 to 2005.

Plate 51. Summary of water quality conditions monitored on water discharged through Big Bend Dam during the 1-year period of October 1, 2004 through September 30, 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Dam Discharge (cfs)	1	8,760	13,750	7,960	0	93,620	-----	-----	-----
Water Temperature (C)	0.1	9	11.9	11.0	1.4	24.7	≤27.0	0	0%
Dissolved Oxygen (mg/l)	0.1	9	8.9	9.1	3.8	13.2	≥ 6.0 ≥ 5.0	2 1	22% 11%
Dissolved Oxygen (% Sat.)	0.1	9	82.9	86.1	44.7	100.6	-----	-----	-----
Specific Conductance (umho/cm)	1	9	624	632	500	680	-----	-----	-----
pH (S.U.)	0.1	9	8.3	8.3	8.0	8.6	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	10	175	177	163	181	-----	-----	-----
Ammonia, Total (mg/l)	0.01	10	0.09	0.06	n.d.	0.27	4.7 [1,2], 1.4 [1,3]	0	0%
Carbon, Total Organic (mg/l)	0.05	10	3.2	3.1	3.0	3.9	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	10	475	455	379	753	1,750[5]	0	0%
Hardness, Total (mg/l)	0.4	3	221	223	221	228	-----	-----	-----
Iron, Dissolved (ug/l)	40	9	-----	n.d.	n.d.	142	-----	-----	-----
Iron, Total (ug/l)	40	10	203	165	70	582	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	10	0.37	0.31	0 20	0.97	-----	-----	-----
Manganese, Dissolved (ug/l)	1	9	11	6	1	53	-----	-----	-----
Manganese, Total (ug/l)	1	10	50	44	14	114	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	10	-----	n.d.	n.d.	0.10	10[5]	0	0%
Phosphorus, Total (mg/l)	0.01	10	0.06	0.03	0.01	0.30	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	9	-----	n.d.	n.d.	n.d.	-----	-----	-----
Sulfate (mg/l)	0.1	10	212	210	190	230	875[5]	0	0%
Suspended Solids, Total (mg/l)	4	10	-----	3	n.d.	16	158[2], 90[3]	0	0%
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6[4]	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	340[2], 150[3], 0.018[4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4[4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	8.9[2], 1.9[3]	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,066[2], 346[3]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	36.5[2], 22.7[3], 1,300[4]	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	154[2], 6.0[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.012[3]	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	2,811[2], 312[3], 610[4]	0	0%
Selenium, Total (ug/l)	4	2	-----	n.d.	n.d.	n.d.	4.6[3], 170[4]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	13.9[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	10	10	10	11	228[2], 208[3], 7,400[4]	0	0%
Pesticide Scan (ug/l)***	0.05	1	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 11.0 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many South Dakota's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 224 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

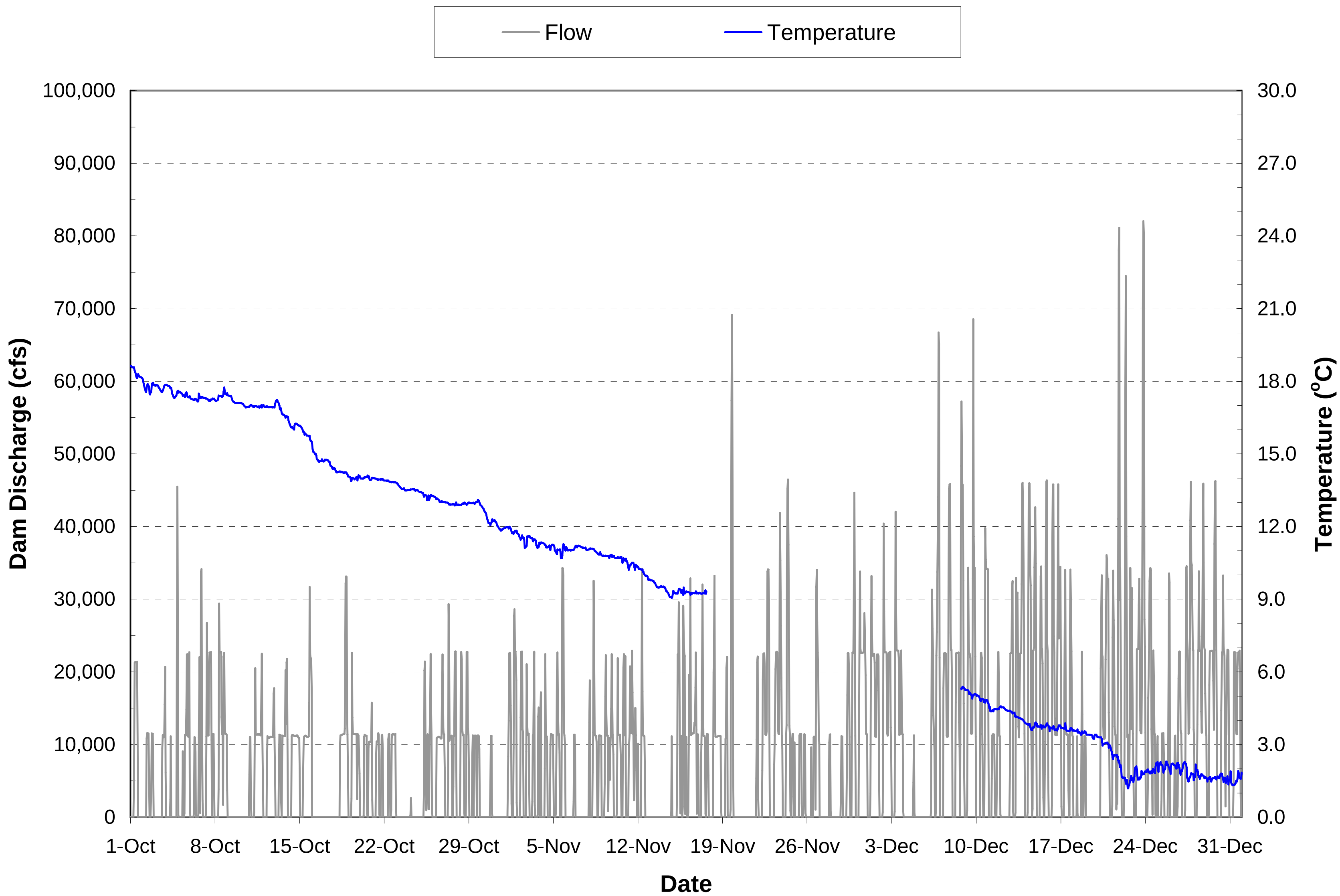


Plate 52. Hourly discharge and water temperature monitored at the Big Bend power plant on water discharged through the dam during the period October through December 2004. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

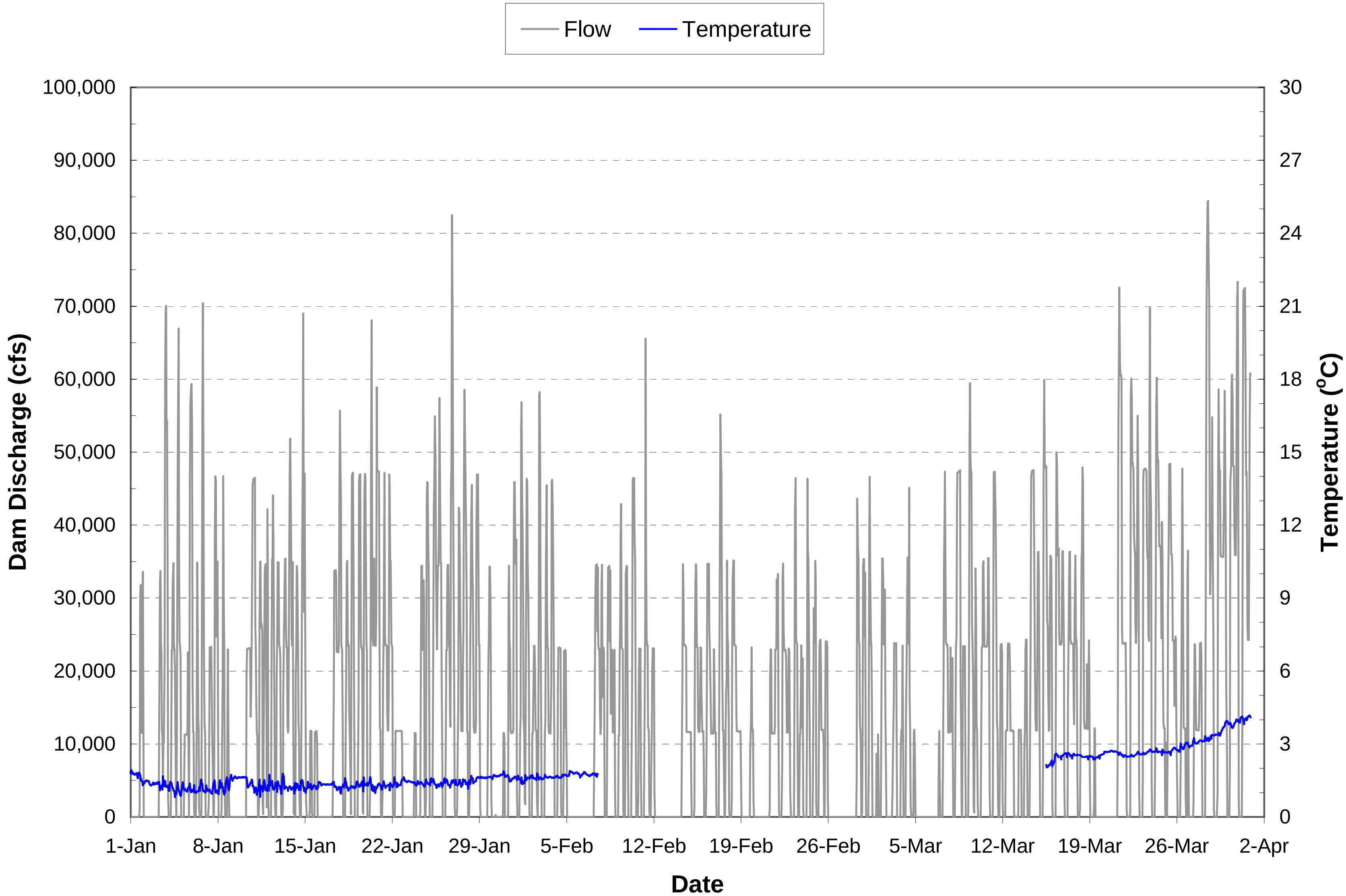


Plate 53. Hourly discharge and water temperature monitored at the Big Bend power plant on water discharged through the dam during the period January through March 2005. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

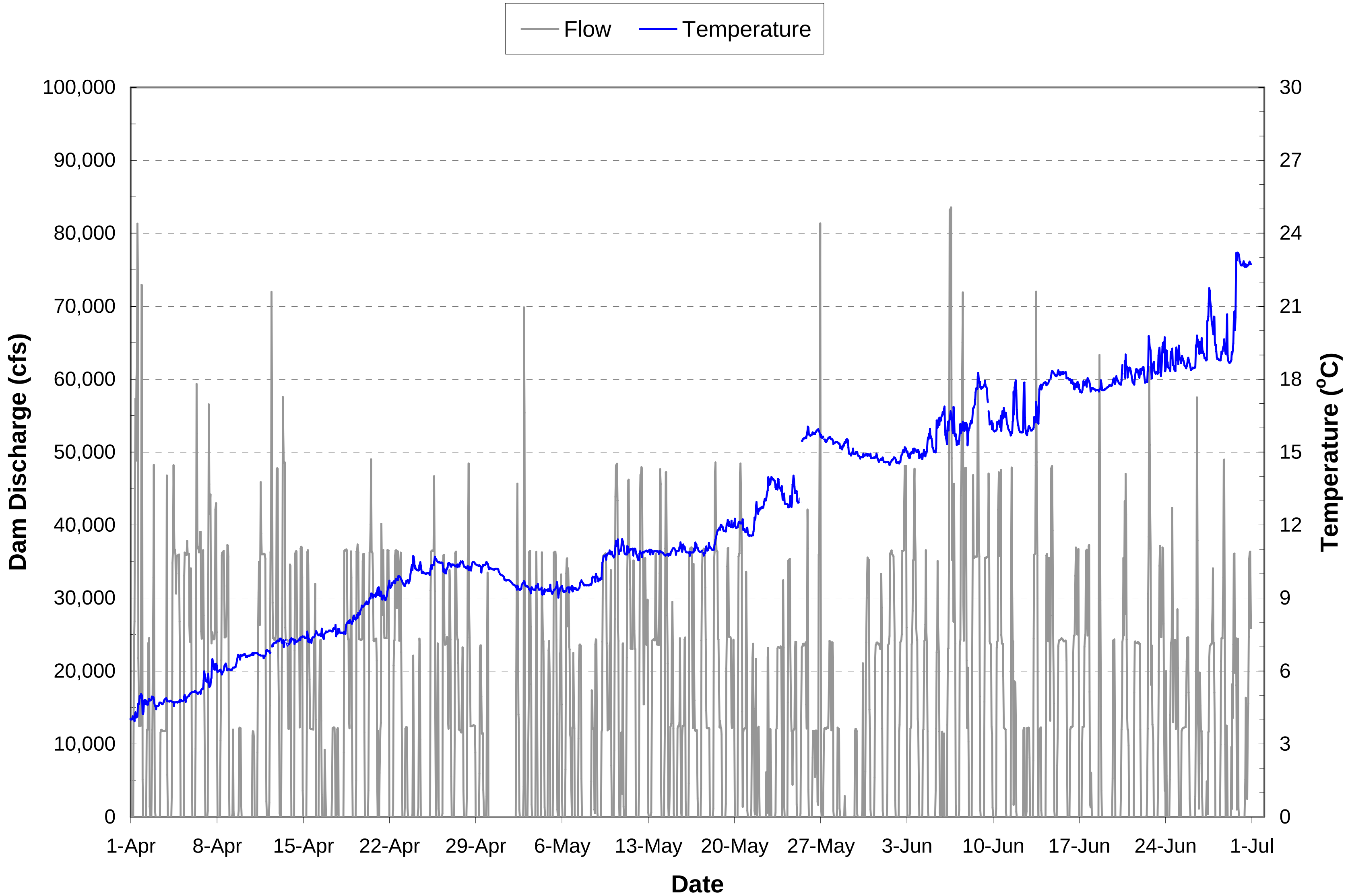


Plate 54. Hourly discharge and water temperature monitored at the Big Bend power plant on water discharged through the dam during the period April through June 2005. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

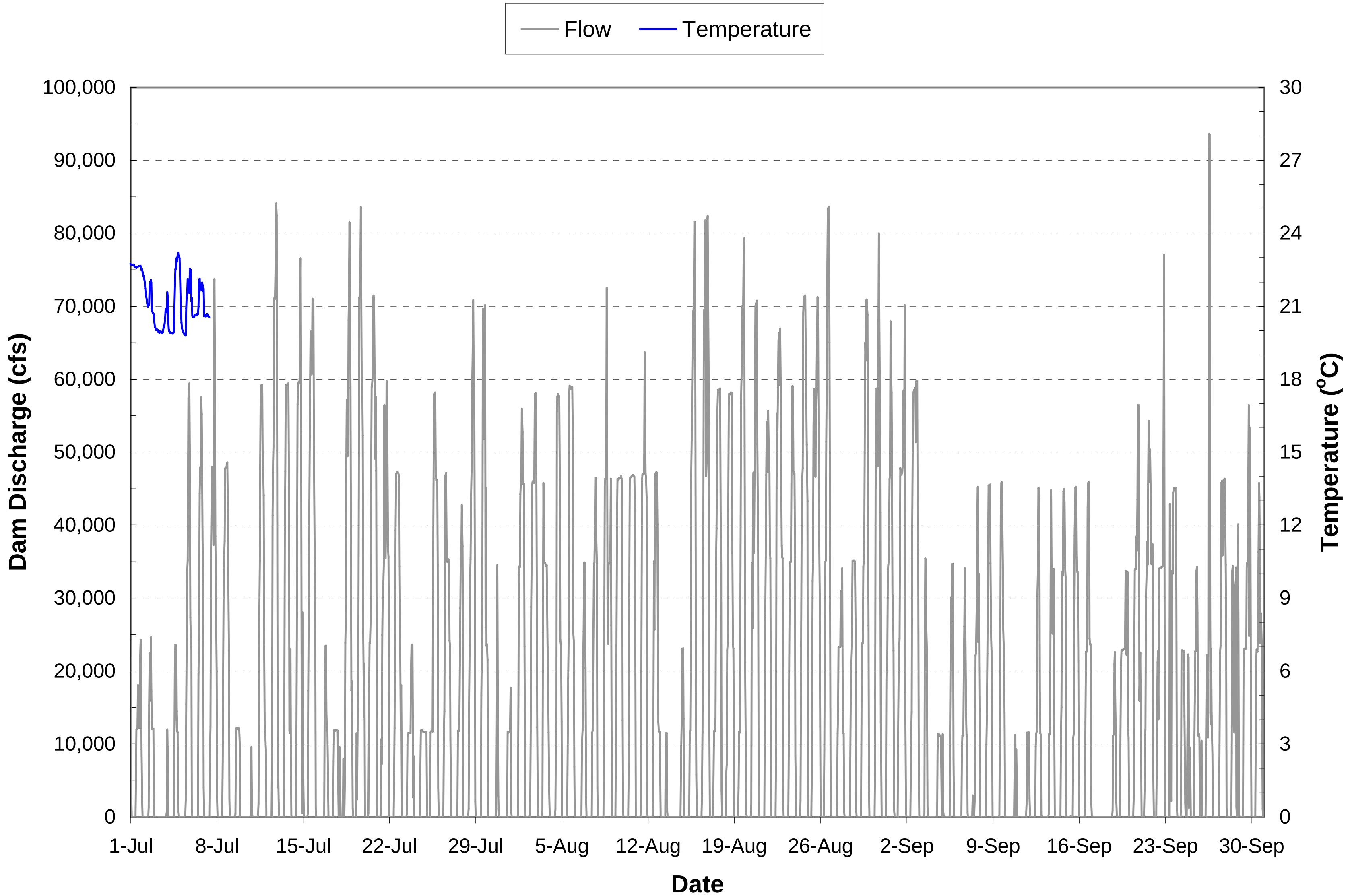


Plate 55. Hourly discharge and water temperature monitored at the Big Bend power plant on water discharged through the dam during the period July through September 2005. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

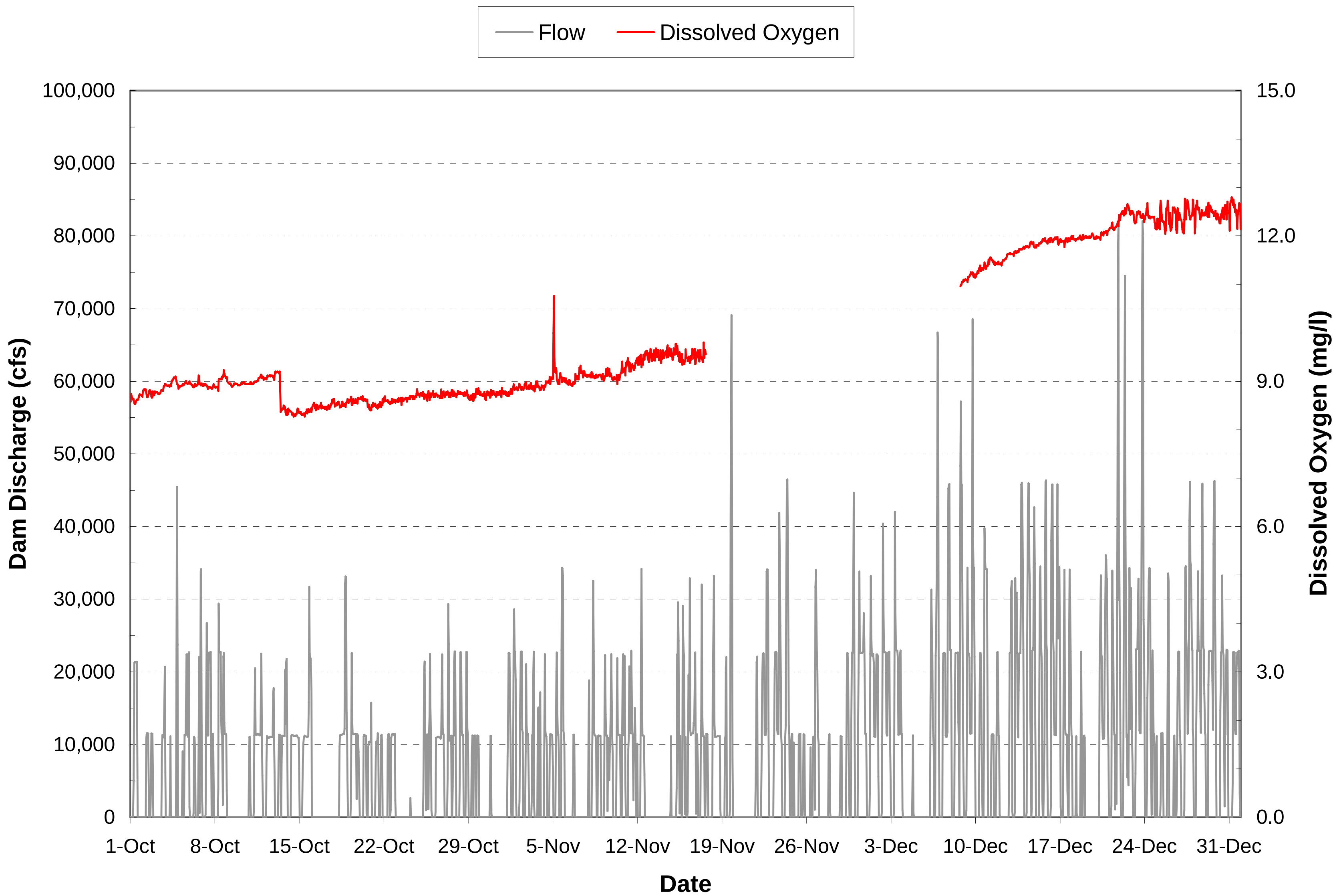


Plate 56. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend power plant on water discharged through the dam during the period October through December 2004. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

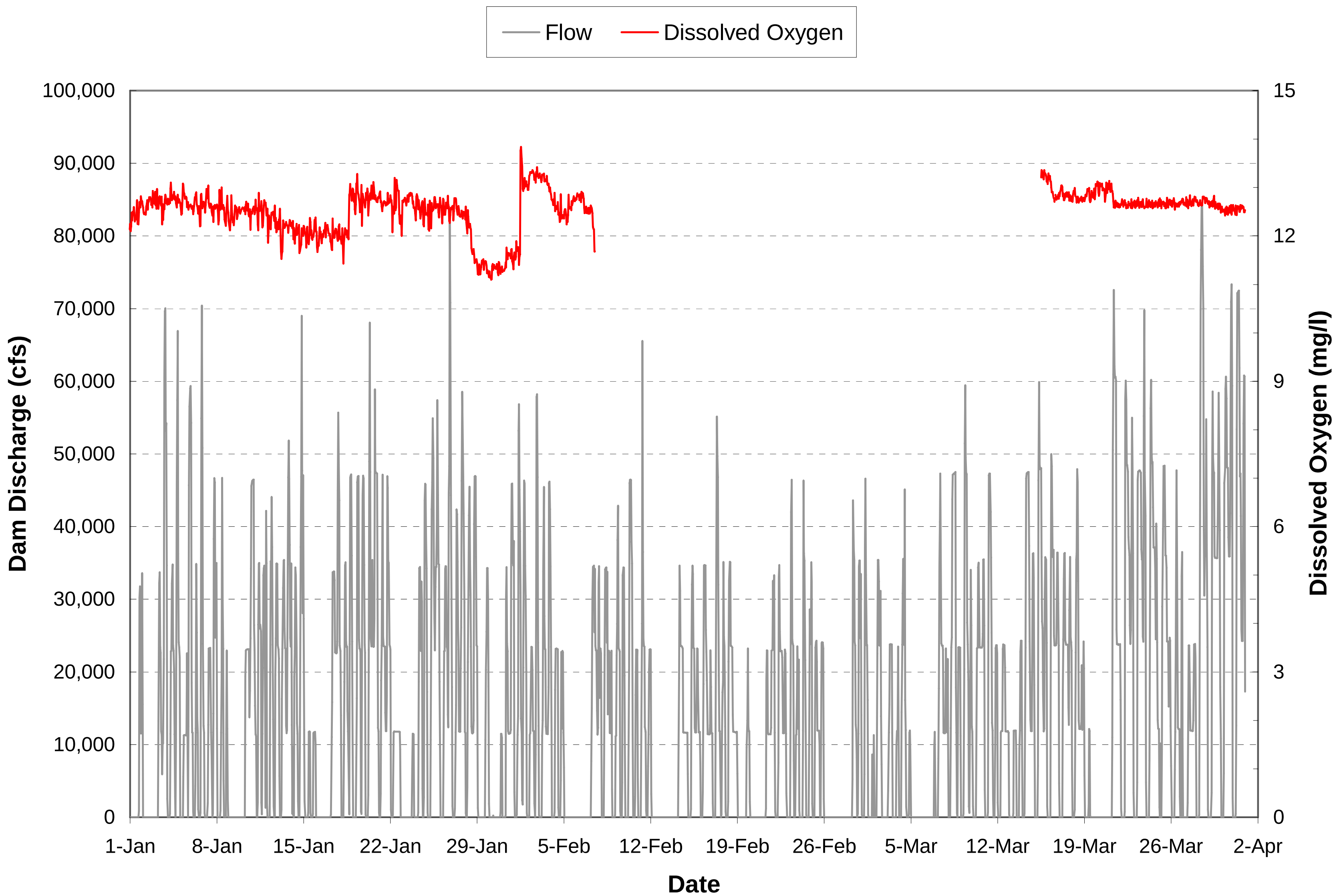


Plate 57. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend power plant on water discharged through the dam during the period January through March 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

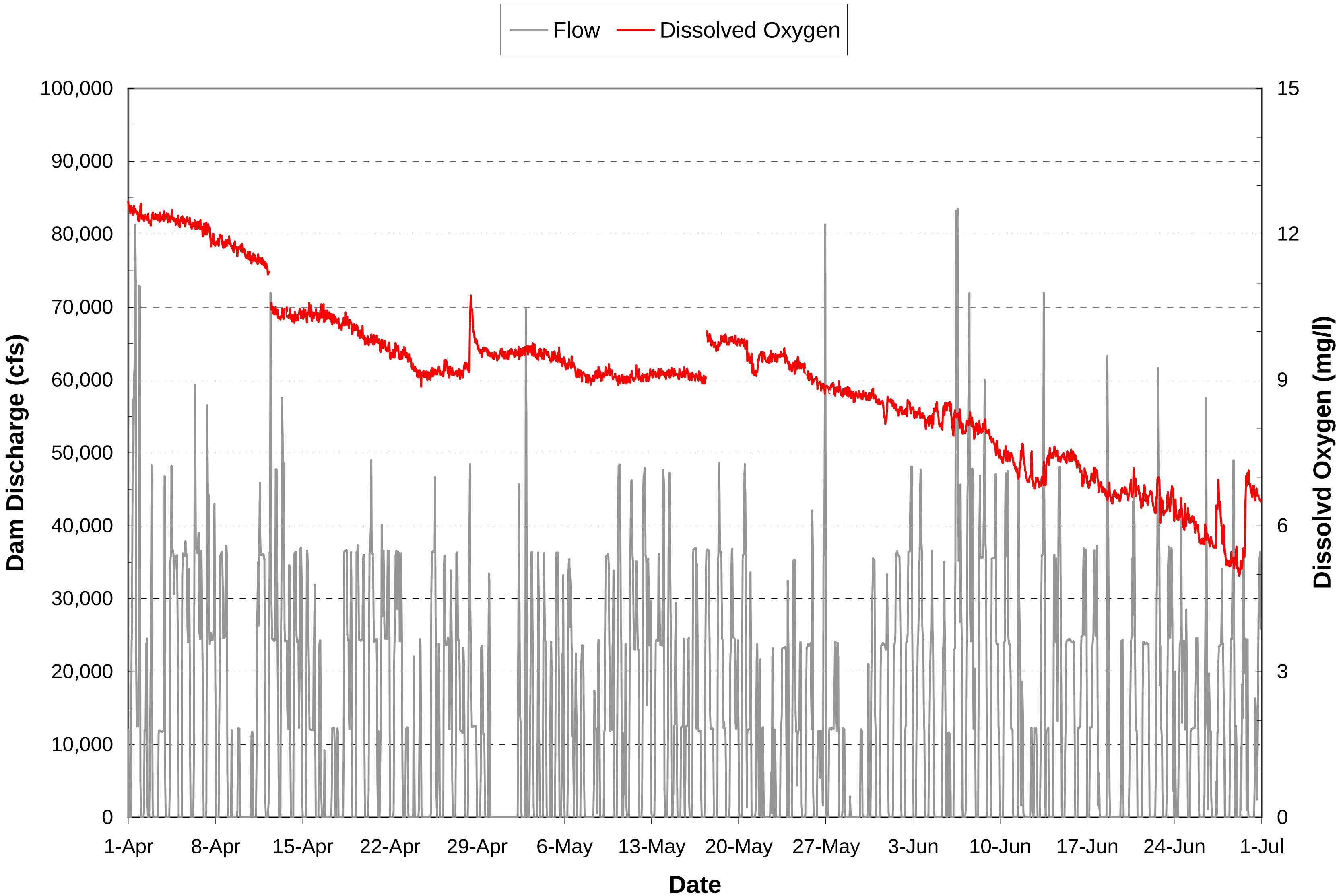


Plate 58. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend power plant on water discharged through the dam during the period April through June 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

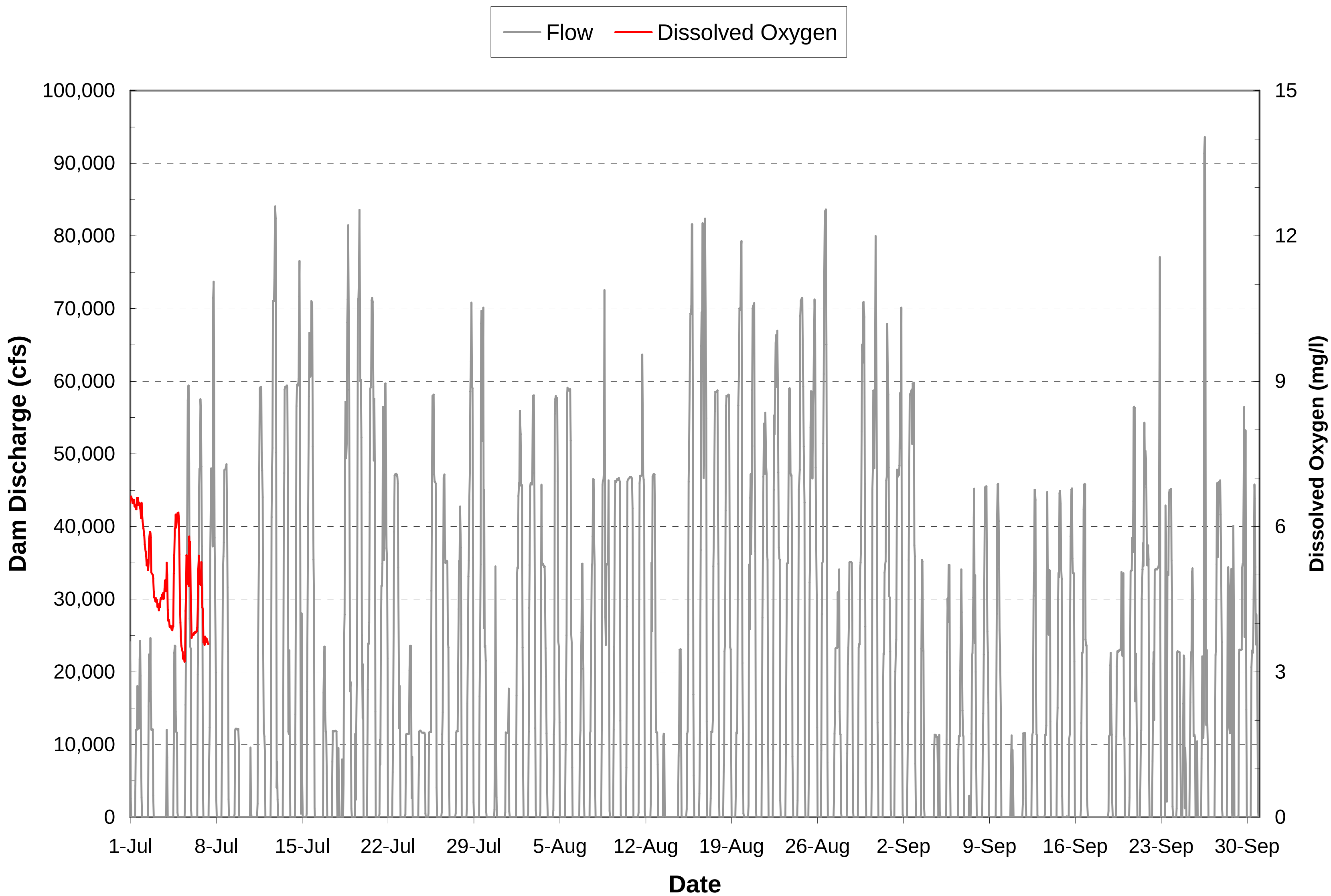


Plate 59. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend power plant on water discharged through the dam during the period July through September 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

Plate 60. Summary of water quality conditions monitored in Fort Randall Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1354.0	1354.0	1348.6	1361.3	-----	-----	-----
Water Temperature (C)	0.1	810	19.4	22.0	5.6	28.1	27.0	3	<1%
Dissolved Oxygen (mg/l)	0.1	792	7.9	7.6	1.8	12.8	≥ 5.0 ≥ 6.0	24 60	3% 8%
Dissolved Oxygen (% Sat.)	0.1	792	88.6	90.7	20.7	109.7	-----	-----	-----
Specific Conductance (umho/cm)	1	810	735	739	571	864	-----	-----	-----
pH (S.U.)	0.1	737	8.3	8.3	7.4	9.0	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	461	4.1	3.3	0.2	32.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	499	377	379	301	441	-----	-----	-----
Secchi Depth (in.)	1	23	110	112	51	216	-----	-----	-----
Alkalinity, Total (mg/l)	7	45	173	174	11	204	-----	-----	-----
Ammonia, Total (mg/l)	0.01	36	0.16	0.09	n.d.	1.30	4.7 [1,2], 0.91 [1,3]	0, 1	0%, <1%
Carbon, Total Organic (mg/l)	0.05	40	3.3	3.1	2.9	4.9	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	314	-----	n.d.	n.d.	9	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	18	-----	1	n.d.	37	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	10	575	525	440	915	1,750[5]	0	0%
Hardness, Total (mg/l)	0.4	16	249	241	220	291	-----	-----	-----
Iron, Total (ug/l)	40	4	77	72	50	114	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	46	-----	0.3	n.d.	2.2	-----	-----	-----
Manganese, Total (ug/l)	1	4	15	14	7	26	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	46	-----	n.d.	n.d.	0.29	10[5]	0	0%
Phosphorus, Total (mg/l)	0.01	46	-----	0.02	n.d.	0.10	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	44	-----	n.d.	n.d.	0.02	-----	-----	-----
Sulfate (mg/l)	0.1	8	231	228	220	255	875[5]	0	0%
Suspended Solids, Total (mg/l)	4	46	-----	n.d.	n.d.	15	158[2], 90[3]	0	0%
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	6[4]	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	340[2], 150[3], 0.018[4]	0/0/b.d.	0%/0%/b.d.
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	4[4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	3.0	9.6[2], 2.0[3]	0, 1	0%, 20%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,128[2], 366[3]	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	39.0[2], 24.1[3], 1,300[4]	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	165[2], 6.5[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	0.02	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	0.08	0.012[3]	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	2,979[2], 331[3], 610[4]	0	0%
Selenium, Total (ug/l)	4	3	-----	n.d.	n.d.	n.d.	4.6[3], 170[4]	0	0%
Silver, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	n.d.	15.7[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Total (ug/l)	3	3	5.5	4.4	3.3	8.7	241[2], 220[3] 7,400[4]	0	0%
Alachlor, Total (ug/l)	0.05	18	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)	0.05	18	-----	n.d.	n.d.	0.12	-----	-----	-----
Metolachlor, Total (ug/l)	0.05	18	-----	n.d.	n.d.	0.16	-----	-----	-----
Pesticide Scan (ug/l)***	0.05	5	-----	n.d.	n.d.	n.d.	****	0	0%
Microcystins, Total (ug/l)	0.2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 3 and 22.0 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many South Dakota's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 241 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 61. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division, and dominant taxa present for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site at Fort Randall Reservoir during the period 2004 through 2005.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	4,925,542	3	0.83	0	-----	0	-----	1	0.09	2	0.08	0	-----	0	-----	0.76
Jul 2004	832,108	0	-----	0	-----	0	-----	2	0.97	2	0.03	0	-----	0	-----	0.79
Aug 2004	75,169,830	6	0.62	3	0.01	0	-----	2	0.16	2	<0.01	2	0.20	1	0.01	1.92
May 2005	1,277,161,733	12	0.97	6	0.02	0	-----	2	0.01	4	<0.01	0	-----	0	-----	1.60
Jun 2005	12,054,751	4	0.41	4	0.19	0	-----	1	0.30	3	0.10	0	-----	0	-----	1.84
Jul 2005	103,882,588	6	0 91	2	<0.01	1	0.06	1	<0.01	3	0.02	0	-----	0	-----	1.43
Aug 2005	131,927,592	5	0.77	4	0.07	1	<0.01	2	0.09	0	-----	1	0.04	1	0.04	1.57
Sep 2005	20,963,108	3	0.15	1	0.01	0	-----	1	0.18	7	0.65	0	-----	0	-----	1.54
Mean*	**203,364,657**	**4.9**	**0.67**	**2.5**	**0.05**	**0.3**	**0.03**	**1.5**	**0.23**	**2.9**	**0.13**	**0.4**	**0.12**	**0.3**	**0.03**	**1.43**

* Mean percent composition represents the mean when taxa of that division are present.

Date	Division	Dominant Taxa*	Percent of Total Biovolume	Date	Division	Dominant Taxa	Percent of Total Biovolume
				May 2005	Bacillariophyta	*Fragilaria crotonensis*	0.47
					Bacillariophyta	*Asterionella formossa*	0.20
					Bacillariophyta	*Stephanodiscus spp.*	0.12
					Bacillariophyta	*Melosira varians*	0.11
June 2004	Bacillariophyta	*Fragilaria crotonensis*	0.81	June 2005	Cryptophyta	*Rhodomonas minuta*	0.30
					Bacillariophyta	*Stephanodiscus spp.*	0.22
					Bacillariophyta	*Cyclotella spp.*	0.17
July 2004	Cryptophyta	*Rhodomonas minuta*	0.60	July 2005	Bacillariophyta	*Fragilaria crotonensis*	0.45
	Cryptophyta	*Cryptomonas spp.*	0.37		Bacillariophyta	*Synedra spp.*	0.33
August 2004	Bacillariophyta	*Tabellaria spp.*	0.23	August 2005	Bacillariophyta	*Cyclotella spp.*	0.48
	Pyrrophyta	*Ceratium hirundinella*	0.20		Bacillariophyta	*Synedra spp.*	0.20
	Bacillariophyta	*Fragilaria crotonensis*	0.19				
	Cryptophyta	*Cryptomonas spp.*	0.14				
	Bacillariophyta	*Asterionella formossa*	0.14				
				September 2005	Cyanobacteria	*Planktolyngbya limnetica*	0.52
					Cyanobacteria	*Oscillatoria spp.*	0.12
					Cryptophyta	*Rhodomonas minuta*	0.11

* Dominant taxa are genera or species (depending on identification level) that comprised more than 10% of the total sample biovolume.

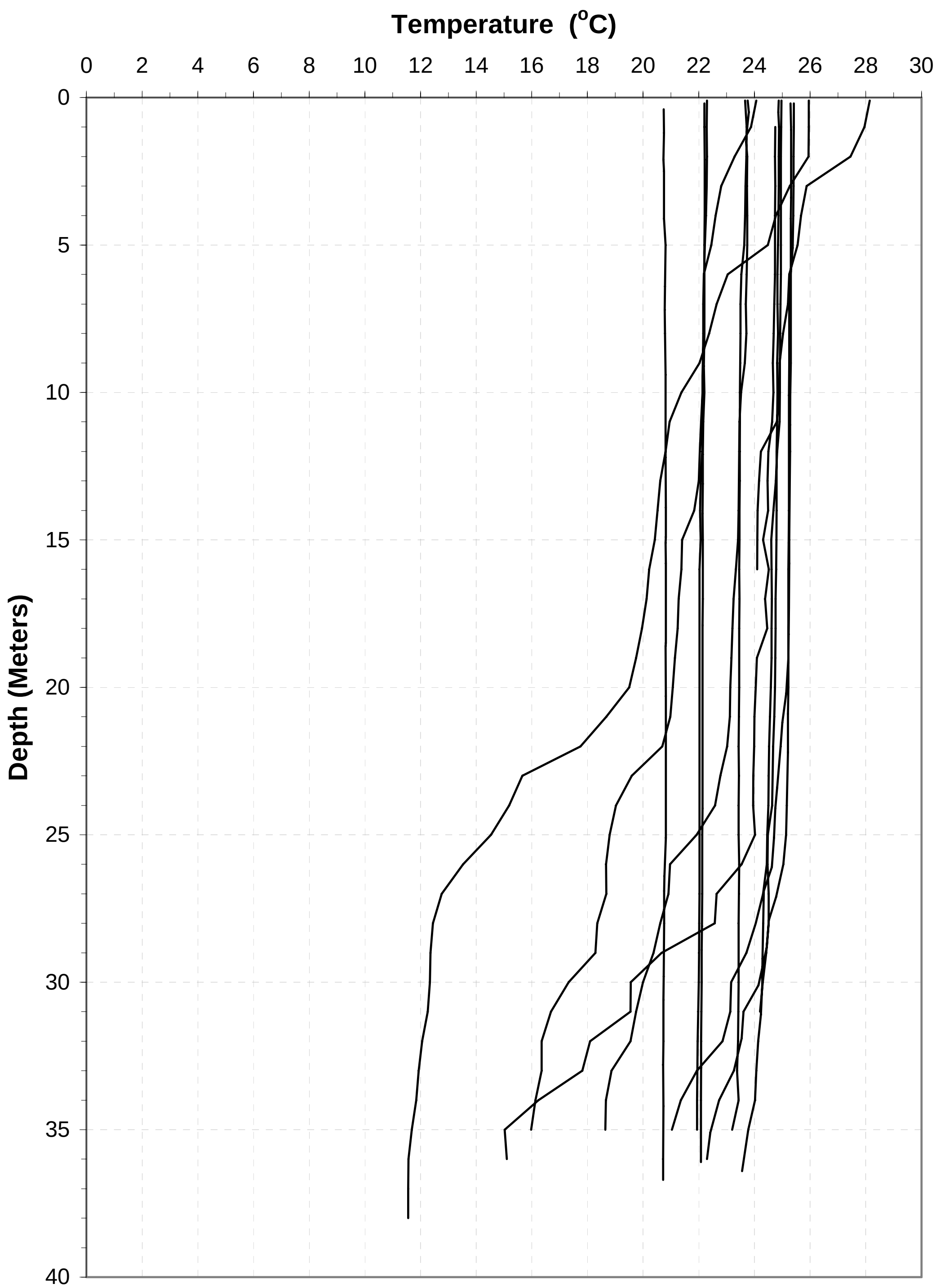


Plate 62. Temperature depth profiles for Fort Randall Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005.

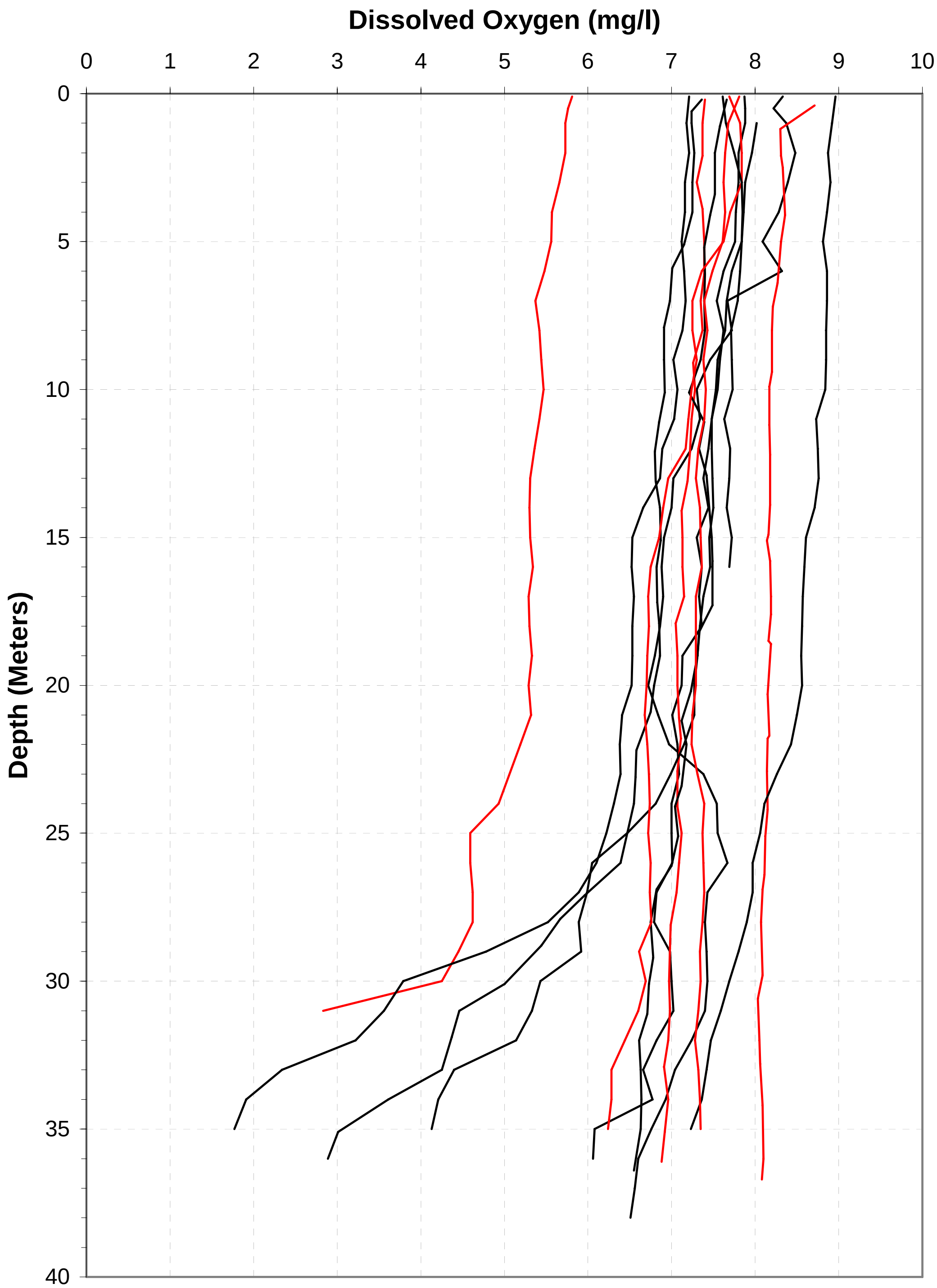


Plate 63. Dissolved oxygen depth profiles for Fort Randall Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005. (Note: Red profiles were measured in the month of September.)

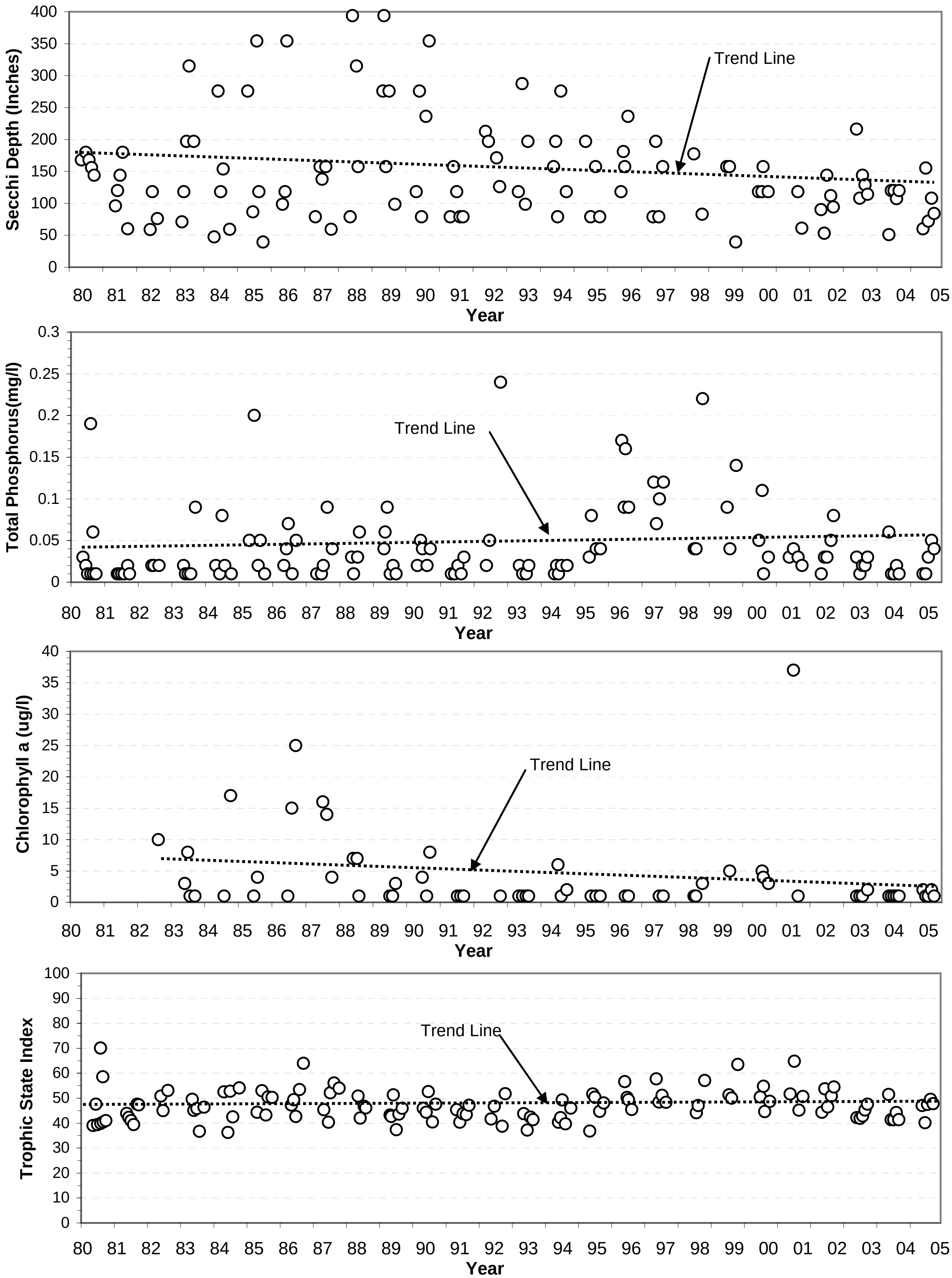


Plate 64. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Fort Randall Reservoir at the near-dam, ambient site over the 26-year period of 1980 to 2005.

Plate 65. Summary of water quality conditions monitored on water discharged through Fort Randall Dam during the 1-year period of October 1, 2004 through September 30, 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Dam Discharge (cfs)	1	8,761	15,237	12,940	0	44,810	-----	-----	-----
Water Temperature (C)	0.1	7,382	11.9	11.6	1.0	25.4	≤27.0	0	0%
Dissolved Oxygen (mg/l)	0.1	6,878	9.7	9.1	2.9	14.0	≥ 6.0 ≥ 5.0	196 135	3% 2%
Dissolved Oxygen (% Sat.)	0.1	6,878	91.0	90.8	34.9	112.6	-----	-----	-----
Specific Conductance (umho/cm)	1	7,382	614	606	467	762	-----	-----	-----
pH (S.U.)	0.1	6,824	8.4	8.3	7.7	8.8	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	10	167	170	130	180	-----	-----	-----
Ammonia, Total (mg/l)	0.01	10	-----	0.06	n.d.	0.20	4.7 (1,2), 1.4 (1,3)	0	0%
Carbon, Total Organic (mg/l)	0.05	10	3.0	3.0	2.5	3.2	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	10	429	446	323	495	1,750(5)	0	0%
Hardness, Total (mg/l)	0.4	2	220	220	217	222	-----	-----	-----
Iron, Dissolved (ug/l)	40	9	-----	n.d.	n.d.	50	-----	-----	-----
Iron, Total (ug/l)	40	9	86	80	50	140	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	10	0.4	0.3	0.2	0.9	-----	-----	-----
Manganese, Dissolved (ug/l)	1	9	-----	2	n.d.	14	-----	-----	-----
Manganese, Total (ug/l)	1	9	19	12	5	47	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	10	-----	n.d.	n.d.	0.10	10(5)	0	0%
Phosphorus, Total (mg/l)	0.01	10	0.04	0.03	n.d.	0.14	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	9	-----	n.d.	n.d.	n.d.	-----	-----	-----
Sulfate (mg/l)	0.1	10	207	210	132	230	875(5)	0	0%
Suspended Solids, Total (mg/l)	4	10	-----	n.d.	n.d.	14	158(2), 90(3)	0	0%
Arsenic, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	n.d.	340(2), 150(3), 0.018(4)	0	0%
Cadmium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	8.9(2), 1.9(3)	0	0%
Chromium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	1,066(2), 346(3)	0	0%
Copper, Dissolved (ug/l)	2	2	4	4	3	5	36.5(2), 22.7(3), 1,300(4)	0	0%
Lead, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	154(2), 6.0(3)	0	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	0.012(3)	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	n.d.	2,811(2), 312(3), 610(4)	0	0%
Selenium, Total (ug/l)	4	2	-----	n.d.	n.d.	n.d.	4.6(3), 170(4)	0	0%
Silver, Dissolved (ug/l)	1	2	-----	n.d.	n.d.	n.d.	13.9(2)	0	0%
Zinc, Dissolved (ug/l)	3	2	10	10	10	11	228(2), 208(3), 7,400(4)	0	0%
Pesticide Scan (ug/l)***	0.05	1	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1)Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 11.6 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Daily maximum criterion for domestic water supply.
Note: Many South Dakota's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 220 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

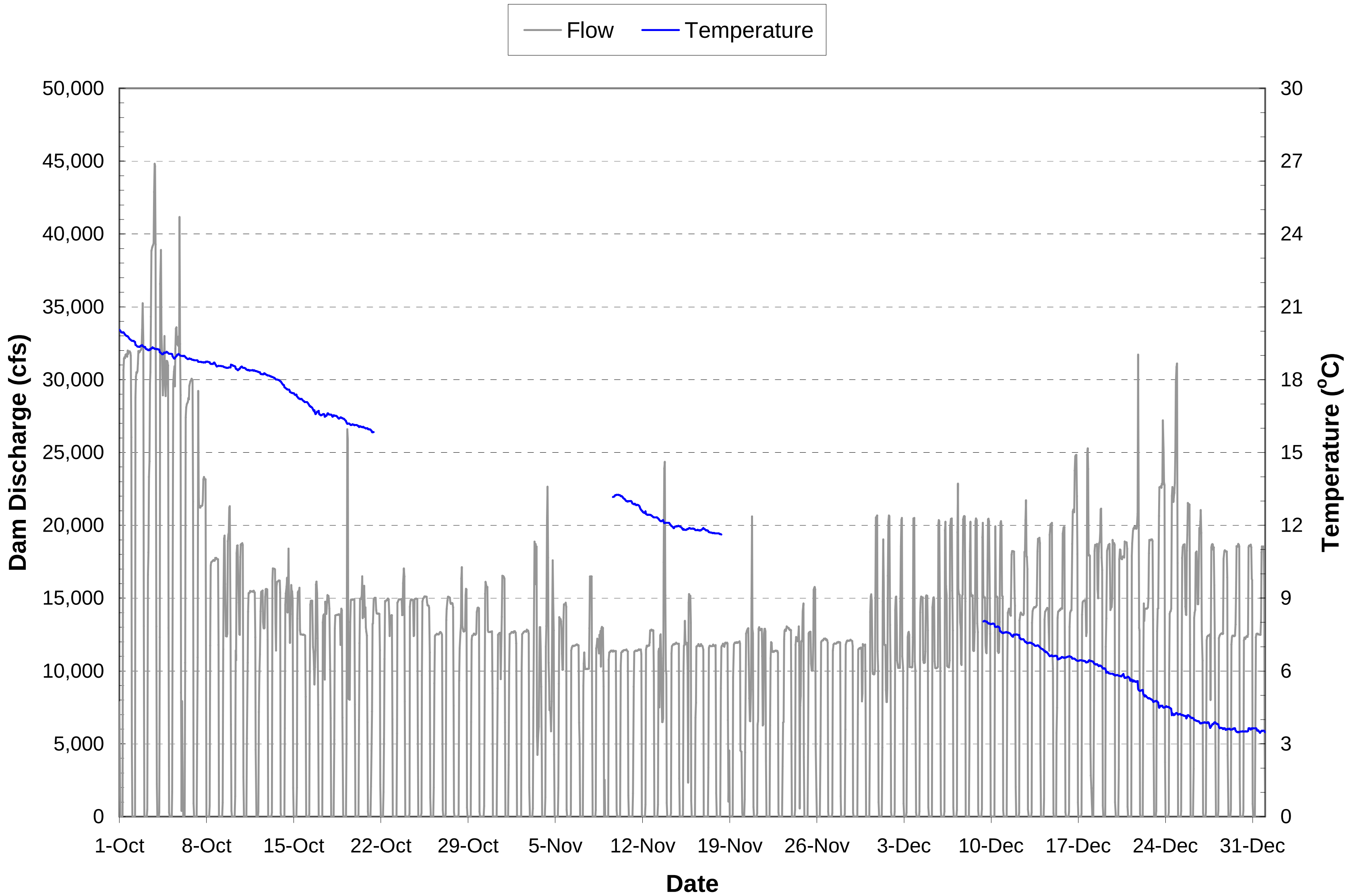


Plate 66. Hourly discharge and water temperature monitored at the Fort Randall power plant on water discharged through the dam during the period October through December 2004. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

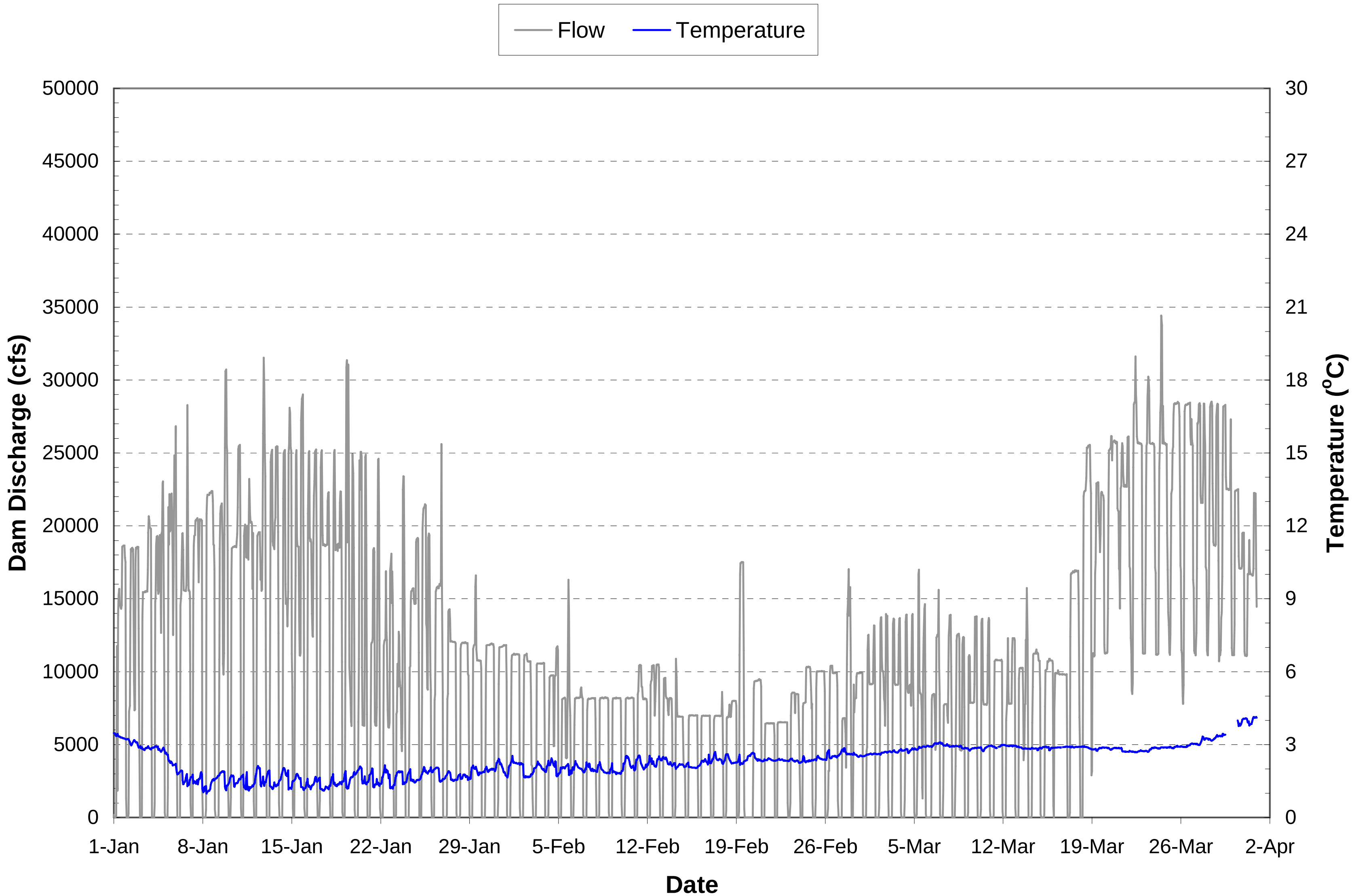


Plate 67. Hourly discharge and water temperature monitored at the Fort Randall power plant on water discharged through the dam during the period January through March 2005. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

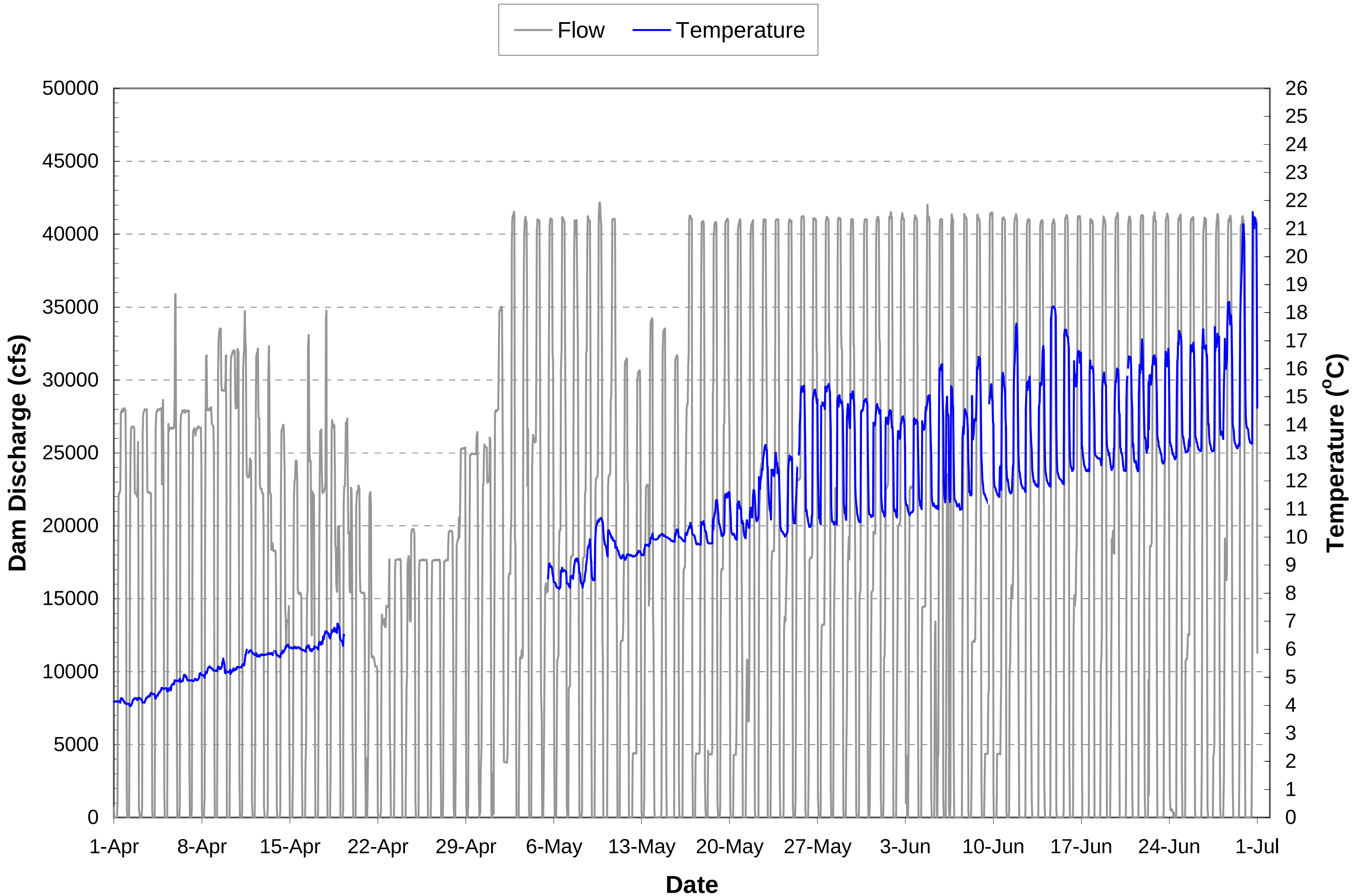


Plate 68. Hourly discharge and water temperature monitored at the Fort Randall power plant on water discharged through the dam during the period April through June 2005. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

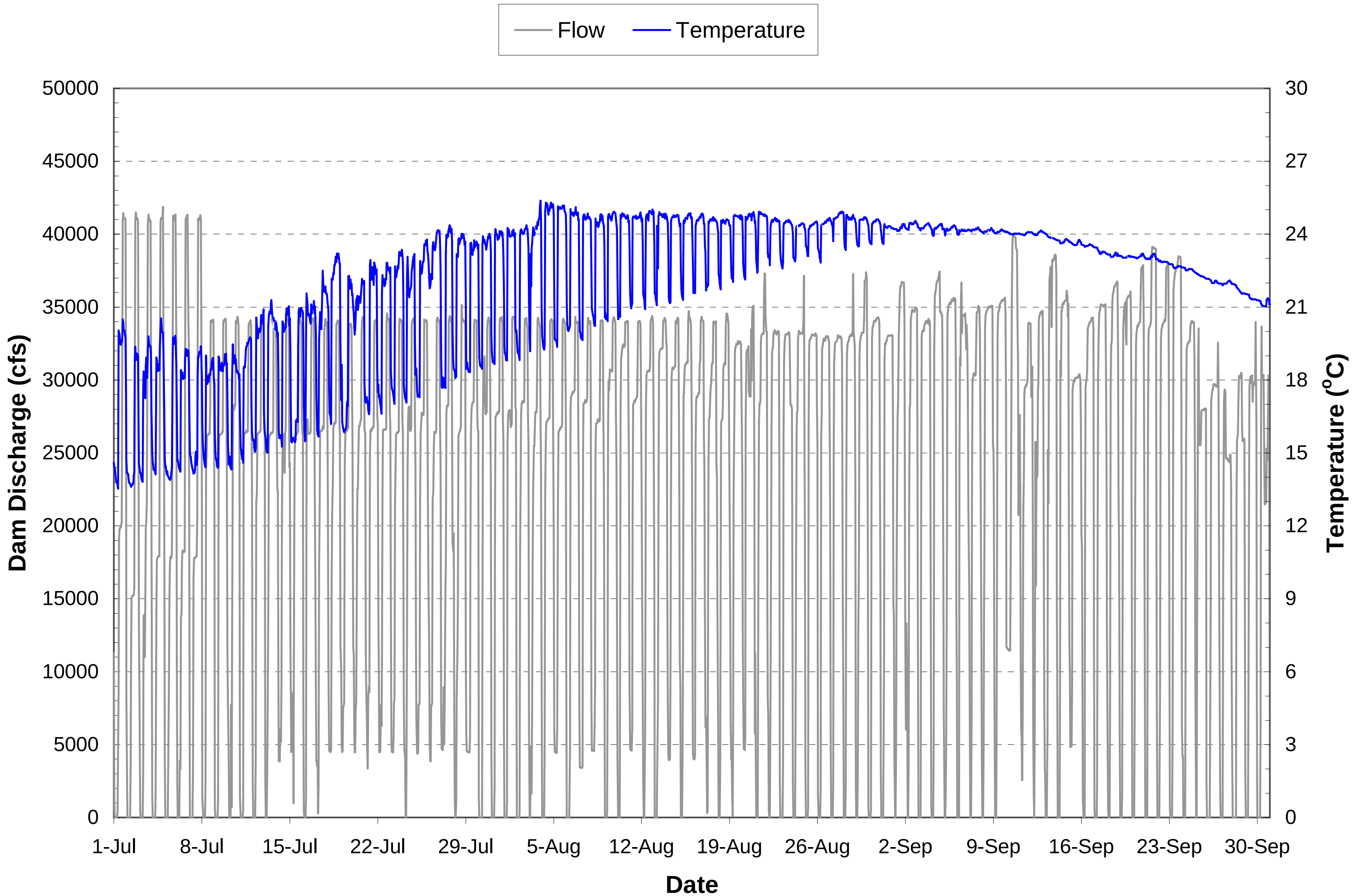


Plate 69. Hourly discharge and water temperature monitored at the Fort Randall power plant on water discharged through the dam during the period July through September 2005.

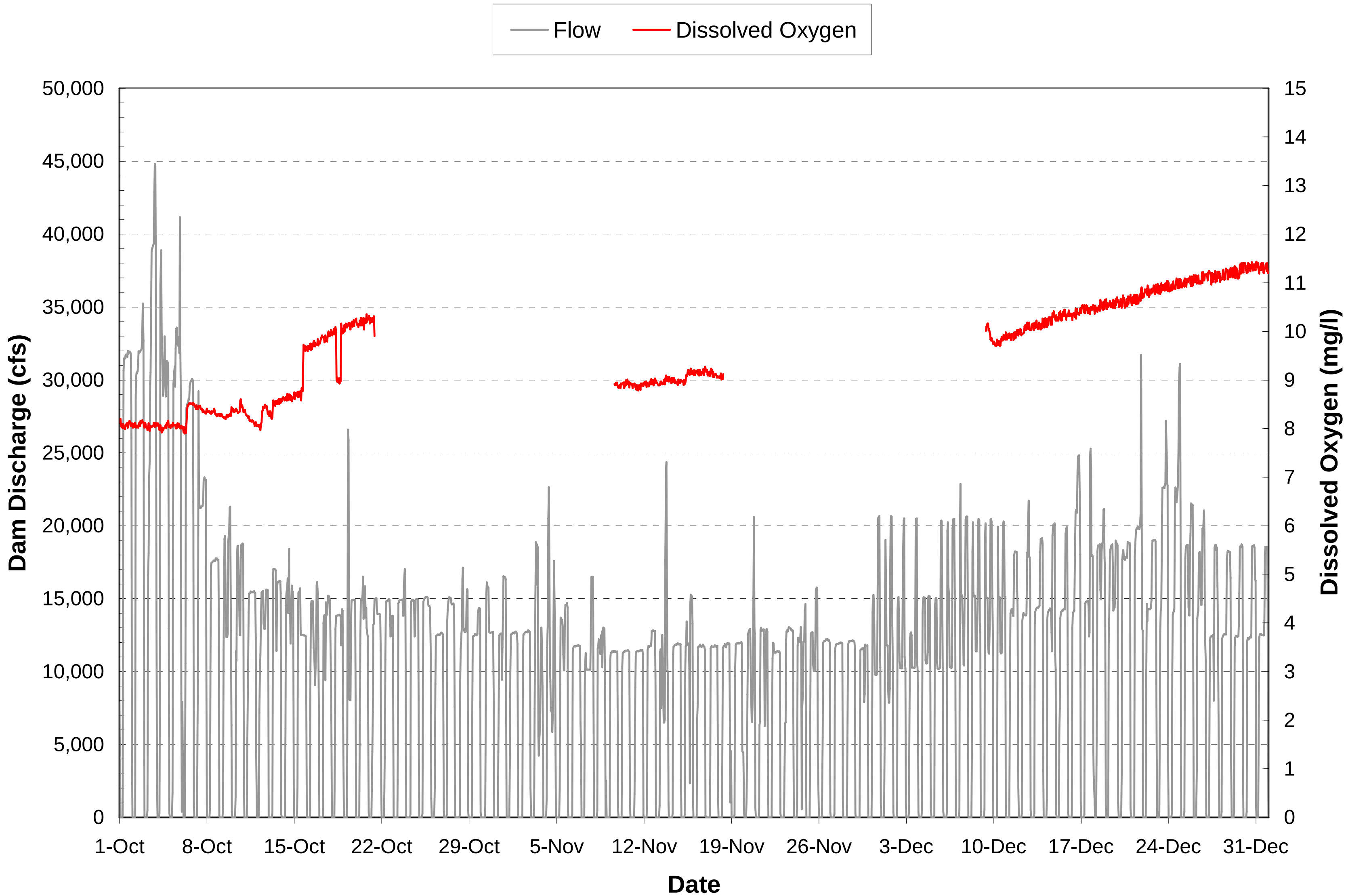


Plate 70. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall power plant on water discharged through the dam during the period October through December 2004. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

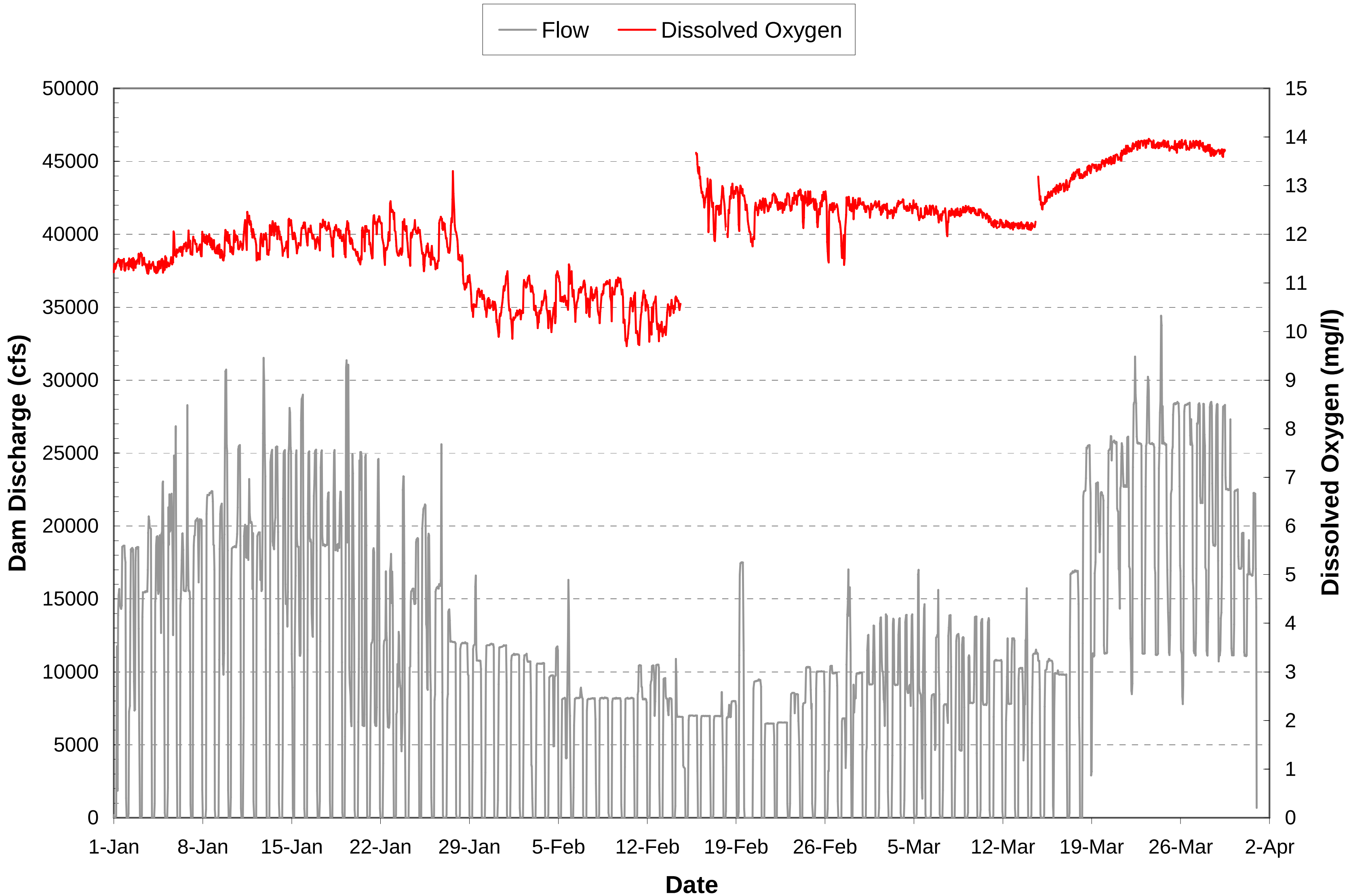


Plate 71. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall power plant on water discharged through the dam during the period January through March 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

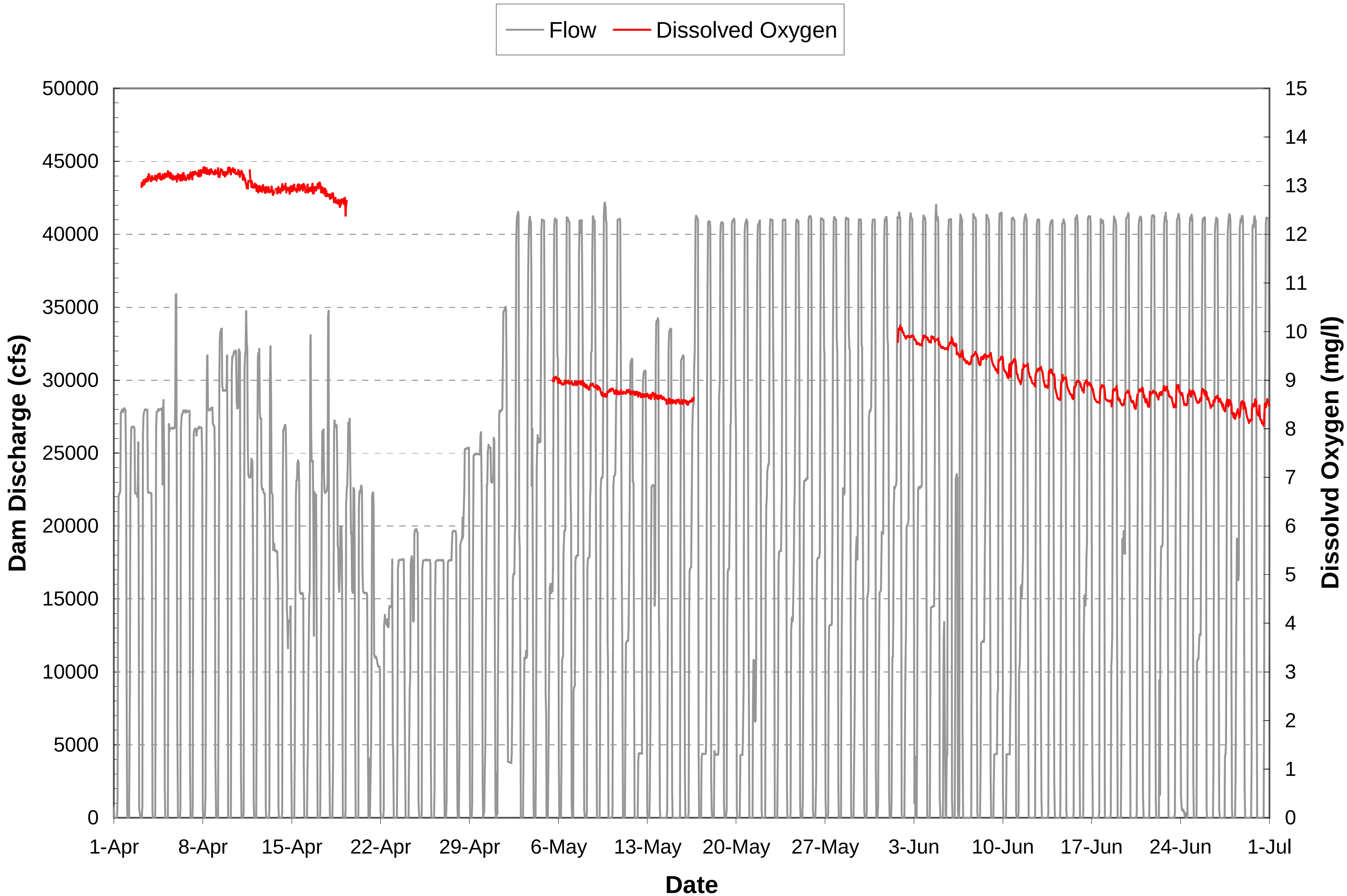


Plate 72. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall power plant on water discharged through the dam during the period April through June 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

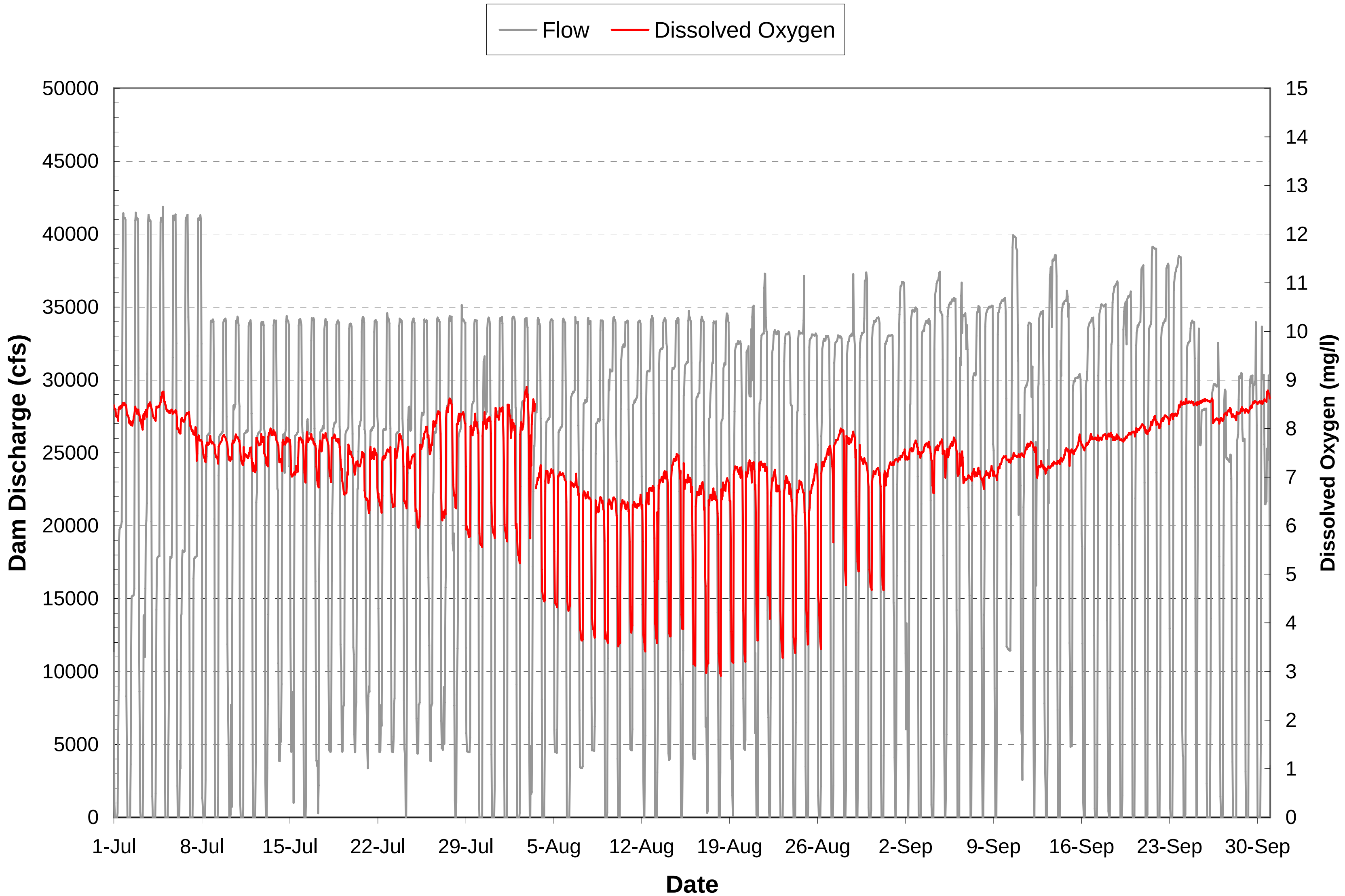


Plate 73. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall power plant on water discharged through the dam during the period July through September 2005.

Plate 74. Summary of water quality conditions monitored in Gavins Point Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1206.4	1206.4	1204.7	1207 9	-----	-----	-----
Water Temperature (C)	0.1	278	21.5	23.0	10.6	28.9	27.0 29.0	6 0	<1% 0%
Dissolved Oxygen (mg/l)	0.1	278	7.4	7.5	1.7	11.6	≥ 5.0 ≥ 6.0	28 58	10% 21%
Dissolved Oxygen (% Sat.)	0.1	278	86.0	90.7	19.3	131.3	-----	-----	-----
Specific Conductance (umho/cm)	1	278	694	689	555	801	-----	-----	-----
pH (S.U.)	0.1	267	8.3	8.3	6.9	9.0	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	132	20	14.5	2.6	94.9	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	155	384	383	281	452	-----	-----	-----
Secchi Depth (in.)	1	25	40	34	20	79	-----	-----	-----
Alkalinity, Total (mg/l)	7	45	183	170	153	740	-----	-----	-----
Ammonia, Total (mg/l)	0.01	35	-----	0.08	n.d.	0.46	4.7 [1,2], 0.85 [1,3]	0, 0	0%, 0%
Carbon, Total Organic (mg/l)	0.05	39	3.7	3.3	2.9	6.6	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	122	9	7	n.d.	29	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	18	6	5	n.d.	20	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	11	966	532	400	4,600	1,750[5]	0	0%
Hardness, Total (mg/l)	0.4	16	248	243	218	306	-----	-----	-----
Iron, Total (ug/l)	40	4	1,560	385	180	5,292	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	45	-----	0.3	n.d.	1.5	-----	-----	-----
Manganese, Total (ug/l)	1	4	109	50	24	314	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	45	-----	n.d.	n.d.	0.77	10[5]	0	0%
Phosphorus, Total (mg/l)	0.01	45	0.05	0.04	n.d.	0.23	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	45	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	0.1	9	221	220	164	299	875[5]	0	0%
Suspended Solids, Total (mg/l)	4	45	14	9	n.d.	216	158[2], 90[3]	1, 1	2%, 2%
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	6[4]	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	340[2], 150[3], 0.018[4]	0/0/b.d.	0%/0%/b.d.
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	4[4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	3.0	9.6[2], 2.0[3]	0, 1	0%, 20%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,128[2], 366[3]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	39.0[2], 24 1[3], 1,300[4]	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	165[2], 6.5[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	0.02	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	0.08	0.012[3]	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	2,979[2], 331[3], 610[4]	0	0%
Selenium, Total (ug/l)	4	3	-----	n.d.	n.d.	n.d.	4.6[3], 170[4]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	15.7[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	4.0.	-----	-----	-----
Zinc, Total (ug/l)	3	3	10.9	4.8	3.8	24.0	241[2], 220[3] 7,400[4]	0	0%
Alachlor, Total (ug/l)	0.05	17	-----	n.d.	n.d.	0.09	-----	-----	-----
Atrazine, Total (ug/l)	0.05	17	-----	0.07	n.d.	0.32	-----	-----	-----
Metolachlor, Total (ug/l)	0.05	17	-----	n.d.	n.d.	0.11	-----	-----	-----
Pesticide Scan (ug/l)***	0.05	5	-----	n.d.	n.d.	n.d.	****	0	0%
Microcystins, Total (ug/l)	0.2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 23.0 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's and South Dakota's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 243 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 75. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division, and dominant taxa present for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site at Gavins Point Reservoir during the period 2004 through 2005.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	2,020,993	1	0.38	0	-----	0	-----	2	0.37	2	0.25	0	-----	0	-----	1.49
Jul 2004	1,260,399	0	-----	0	-----	0	-----	1	0.27	2	0.73	0	-----	0	-----	0.68
Aug 2004	428,086,948	7	0.33	3	<0.01	1	0.01	2	0.06	2	<0.01	1	0.61	1	<0.01	1.24
May 2005	170,642,733	6	0.86	3	0.08	0	-----	1	0.05	1	<0.01	0	-----	0	-----	1.29
Jun 2005	75,346,609	3	0.78	3	0.03	0	-----	1	0.15	3	<0.01	1	0.03	0	-----	1.35
Jul 2005	621,134,038	10	0.93	3	0.06	1	<0.01	1	<0.01	3	<0.01	0	-----	0	-----	1.61
Aug 2005	400,199,396	7	0.55	6	0.02	2	0.05	1	0.26	4	0.04	3	0.06	2	0.04	2.28
Sep 2005	337,716,027	11	0.49	10	0.04	0	-----	2	0.37	6	0.03	2	0.06	2	0.01	2.21
Mean*	**254,550,893**	**5.6**	**0.62**	**3.5**	**0.04**	**0.5**	**0.02**	**1.4**	**0.19**	**2.9**	**0.13**	**0.9**	**0.19**	**0.6**	**0.02**	**1.52**

* Mean percent composition represents the mean when taxa of that division are present.

Date	Division	Dominant Taxa*	Percent of Total Biovolume	Date	Division	Dominant Taxa	Percent of Total Biovolume
				May 2005	Bacillariophyta	*Fragilaria crotonensis*	0.62
					Bacillariophyta	*Asterionella formossa*	0.19
Jun 2004	Bacillariophyta	*Fragilaria spp.*	0.38	June 2005	Bacillariophyta	*Aulacoseira granulata*	0.54
	Cryptophyta	*Cryptomonas spp.*	0.20		Bacillariophyta	*Stephanodiscus spp.*	0.21
	Cryptophyta	*Rhodomonas minuta*	0.17		Cryptophyta	*Rhodomonas minuta*	0.15
	Cyanobacteria	*Aphanothece spp.*	0.17				
Jul 2004	Cyanobacteria	*Aphanocapsa spp.*	0.71	July 2005	Bacillariophyta	*Cyclotella spp.*	0.47
	Cryptophyta	*Rhodomonas minuta*	0.28		Bacillariophyta	*Fragilaria crotonensis*	0.22
					Bacillariophyta	*Aulacoseira spp.*	0.15
Aug 2004	Pyrrophyta	*Ceratium hirundinella*	0.61	August 2005	Bacillariophyta	*Fragilaria crotonensis*	0.29
	Bacillariophyta	*Fragilaria crotonensis*	0.23		Cryptophyta	*Cryptomonas spp.*	0.19
				September 2005	Cryptophyta	*Rhodomonas minuta*	0.35
					Bacillariophyta	*Aulacoseira granulata*	0.19
					Bacillariophyta	*Fragilaria crotonensis*	0.10

* Dominant taxa are genera or species (depending on identification level) that comprised more than 10% of the total sample biovolume.

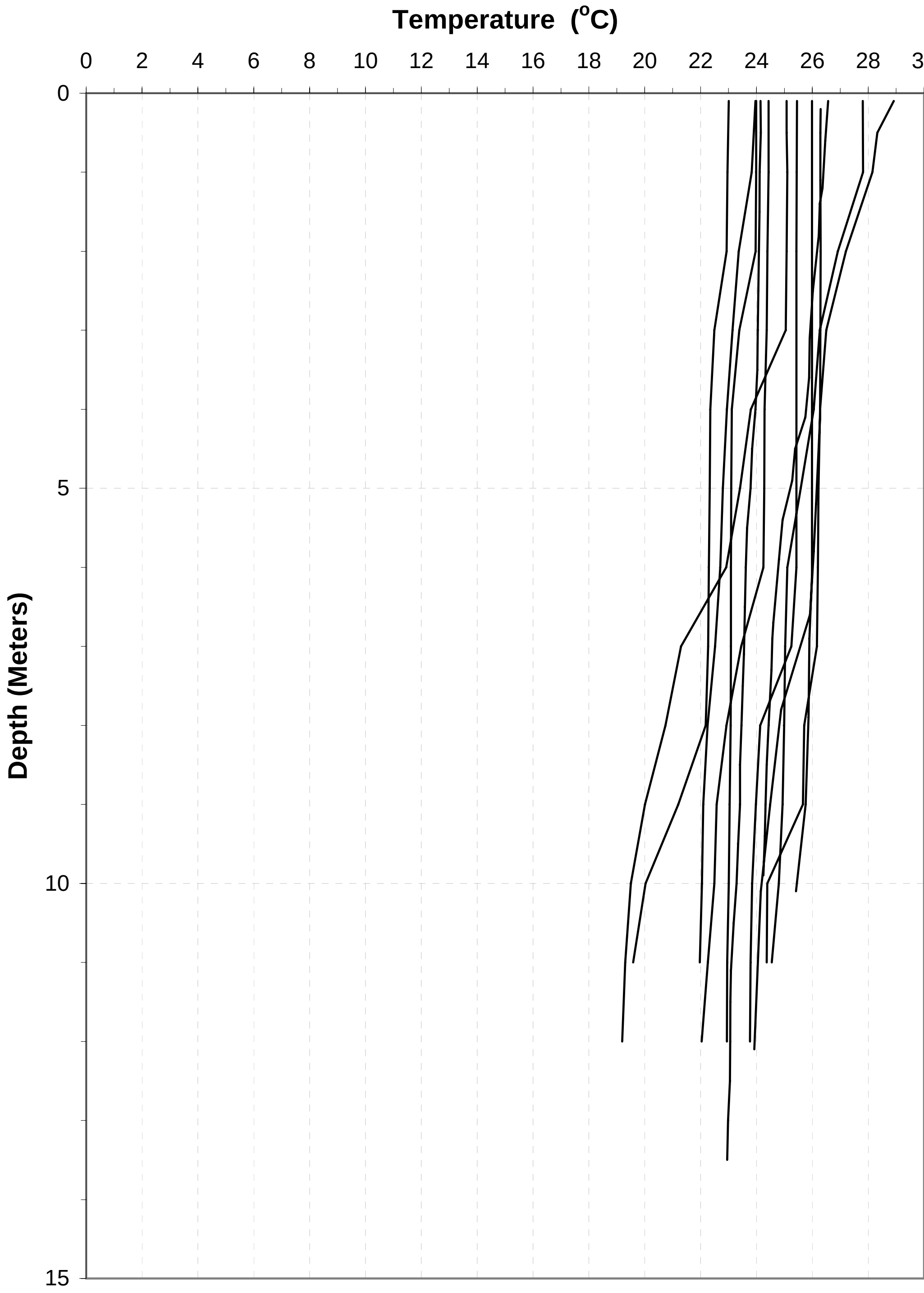


Plate 76. Temperature depth profiles for Gavins Point Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005.

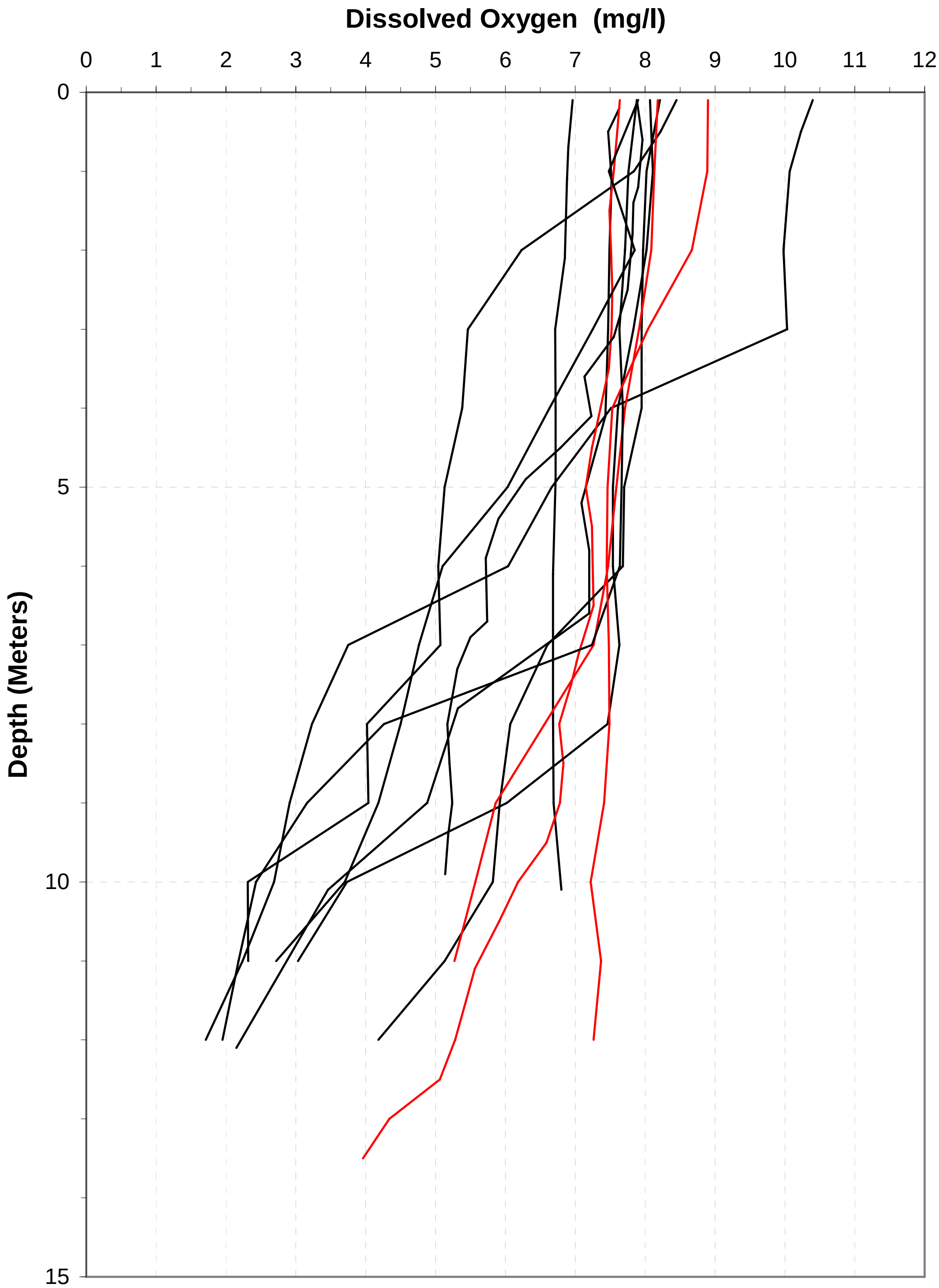


Plate 77. Dissolved oxygen depth profiles for Gavins Point Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the months of July, August, and September over the 5-year period of 2001 to 2005. (Note: Red profiles were measured in the month of September.)

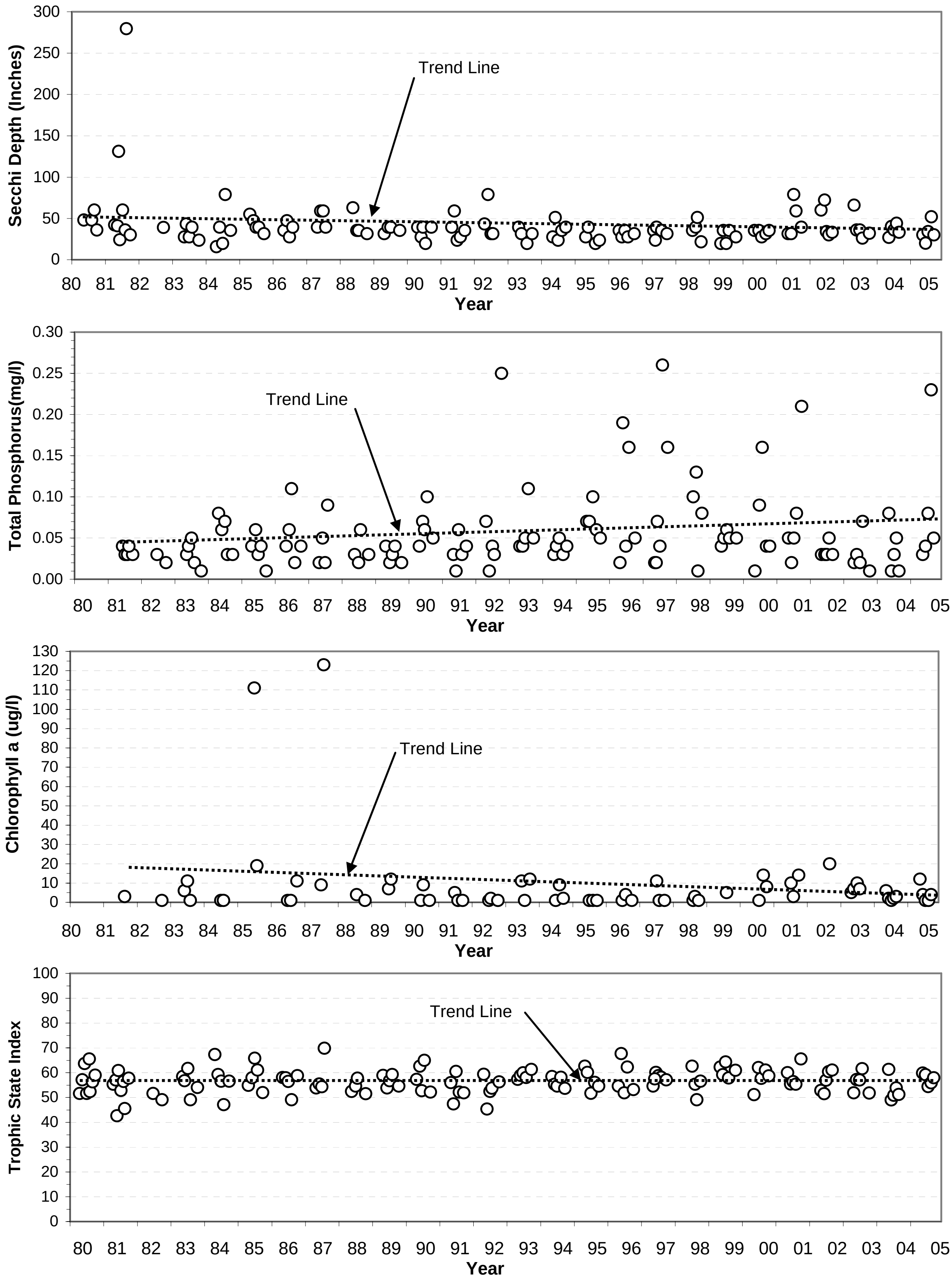


Plate 78. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Gavins Point Reservoir at the near-dam, ambient site over the 26-year period of 1980 to 2005.

Plate 79. Summary of water quality conditions monitored on water discharged through Gavins Point Dam during the 1-year period of October 1, 2004 through September 30, 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Dam Discharge (cfs)	1	8,761	17,247	18,510	0	26,090	-----	-----	-----
Water Temperature (C)	0.1	7,087	13.1	12.6	0.2	27.8	≤27.0 ≤29.0	57 0	1% 0%
Dissolved Oxygen (mg/l)	0.1	5,630	9.5	8.8	2.9	14.2	≥ 6.0 ≥ 5.0	41 1	1% <1%
Dissolved Oxygen (% Sat.)	0.1	5,630	94.6	93.2	36.8	138.1	-----	-----	-----
Specific Conductance (umho/cm)	1	7,087	611	599	433	788	-----	-----	-----
pH (S.U.)	0.1	7,087	8.4	8.3	7.8	9.0	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	11	165	170	141	179	-----	-----	-----
Ammonia, Total (mg/l)	0.01	11	0.11	0.07	n.d.	0.32	4.7 [1,2], 1.6 [1,3]	0	0%
Carbon, Total Organic (mg/l)	0.05	11	3.1	3.0	2.8	3.6	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	11	439	440	374	542	1,750[5]	0	0%
Hardness, Total (mg/l)	0.4	3	215	216	211	217	-----	-----	-----
Iron, Dissolved (ug/l)	40	10	-----	n.d.	n.d.	246	-----	-----	-----
Iron, Total (ug/l)	40	11	378	370	100	616	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	11	0.4	0.3	0.2	1.0	-----	-----	-----
Manganese, Dissolved (ug/l)	1	10	-----	n.d.	n.d.	71	-----	-----	-----
Manganese, Total (ug/l)	1	11	64	51	22	196	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	11	-----	0.06	n.d.	0.28	10[5]	0	0%
Phosphorus, Total (mg/l)	0.01	11	0.07	0.05	0.03	0.18	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	10	-----	n.d.	n.d.	0.02	-----	-----	-----
Sulfate (mg/l)	0.1	11	194	191	145	230	875[5]	0	0%
Suspended Solids, Total (mg/l)	4	11	13	12	6	20	158[2], 90[3]	0	0%
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6[4]	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	340[2], 150[3], 0.018[4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4[4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	8.5[2], 1.8[3]	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,031[2], 334[3]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	35.2[2], 21.9[3], 1,300[4]	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	147[2], 5.7[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.012[3]	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	2,715[2], 302[3], 610[4]	0	0%
Selenium, Total (ug/l)	4	2	-----	n.d.	n.d.	n.d.	4.6[3], 170[4]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	13.0[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	4	220[2], 201[3], 7,400[4]	0	0%
Pesticide Scan (ug/l)***	0.05	1	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 12.6 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Daily maximum criterion for domestic water supply.
Note: Many of South Dakota's and Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 216 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

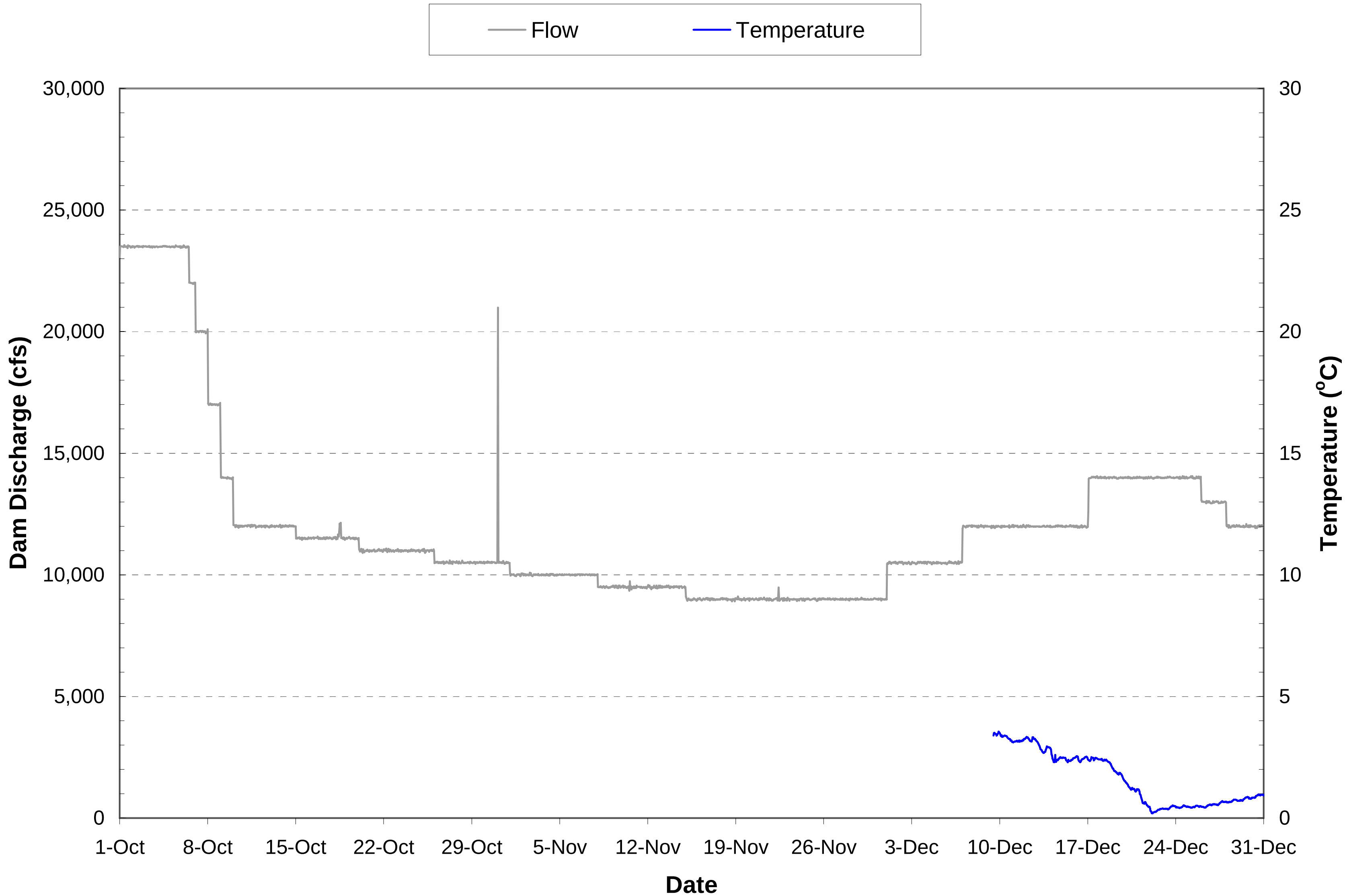


Plate 80. Hourly discharge and water temperature monitored at the Gavins Point power plant on water discharged through the dam during the period October through December 2004. (Note gaps in temperature plot represents periods when monitoring equipment was not operational.)

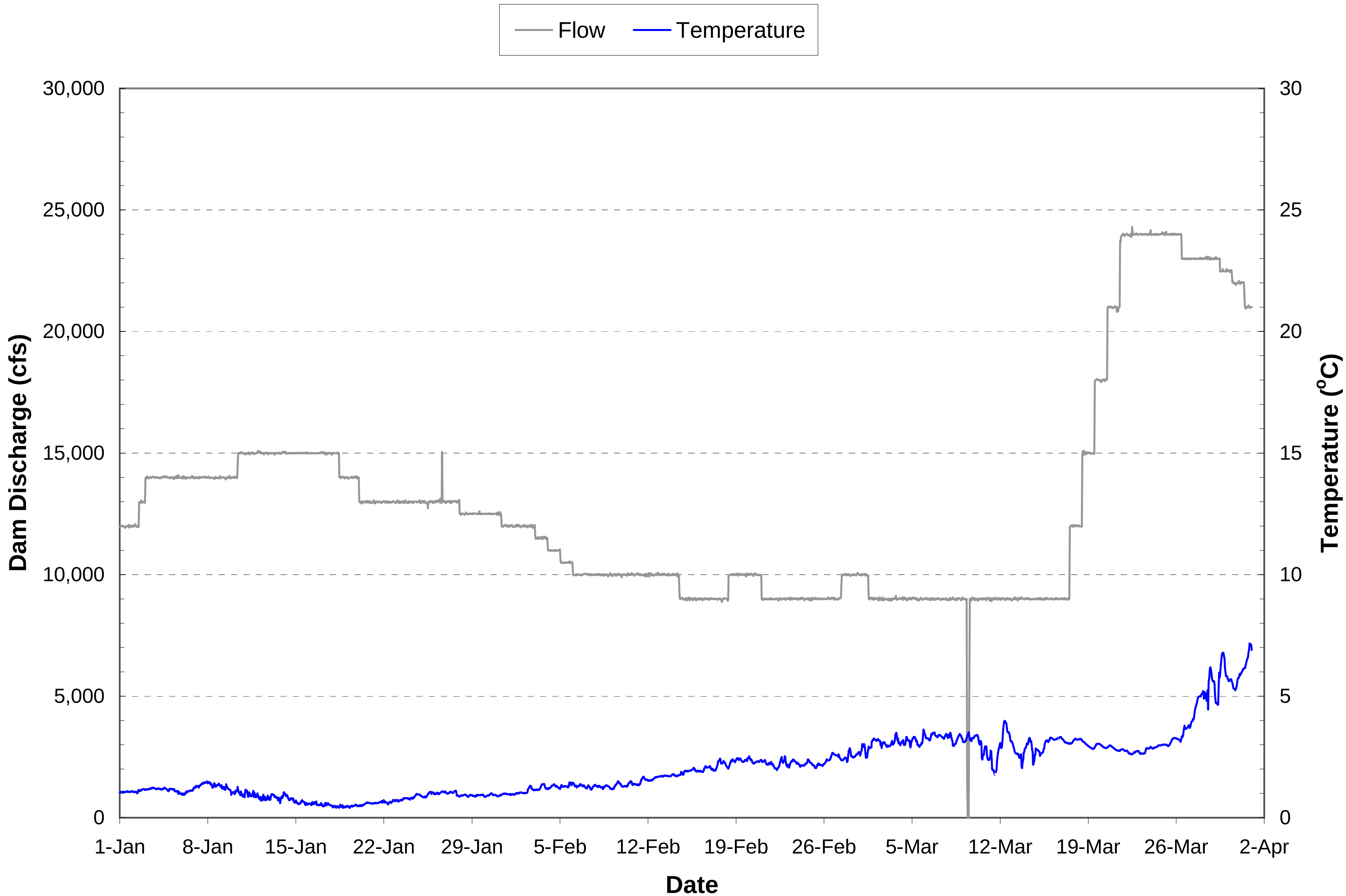


Plate 81. Hourly discharge and water temperature monitored at the Gavins Point power plant on water discharged through the dam during the period January through March 2005.

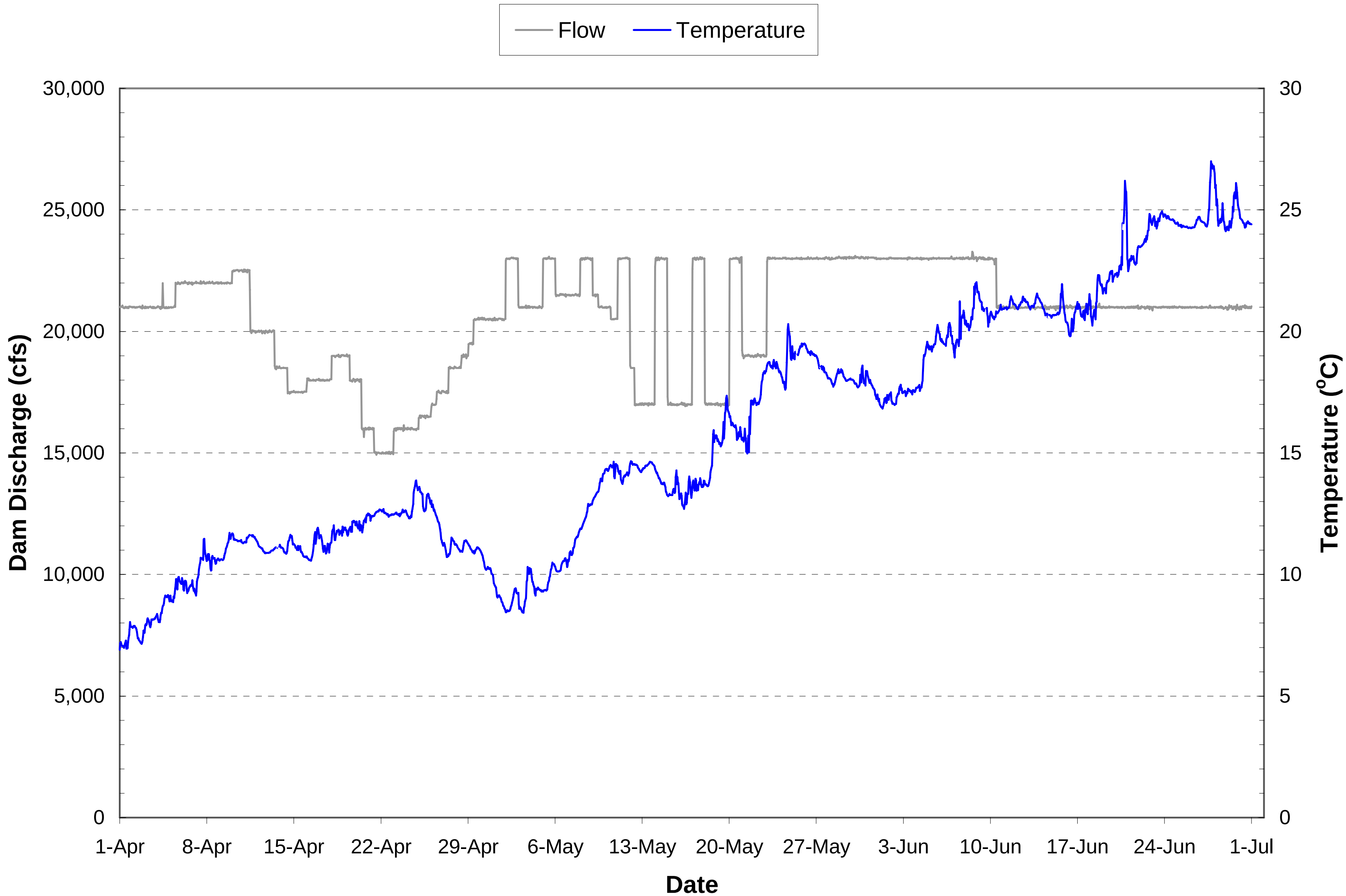


Plate 82. Hourly discharge and water temperature monitored at the Gavins Point power plant on water discharged through the dam during the period April through June 2005.

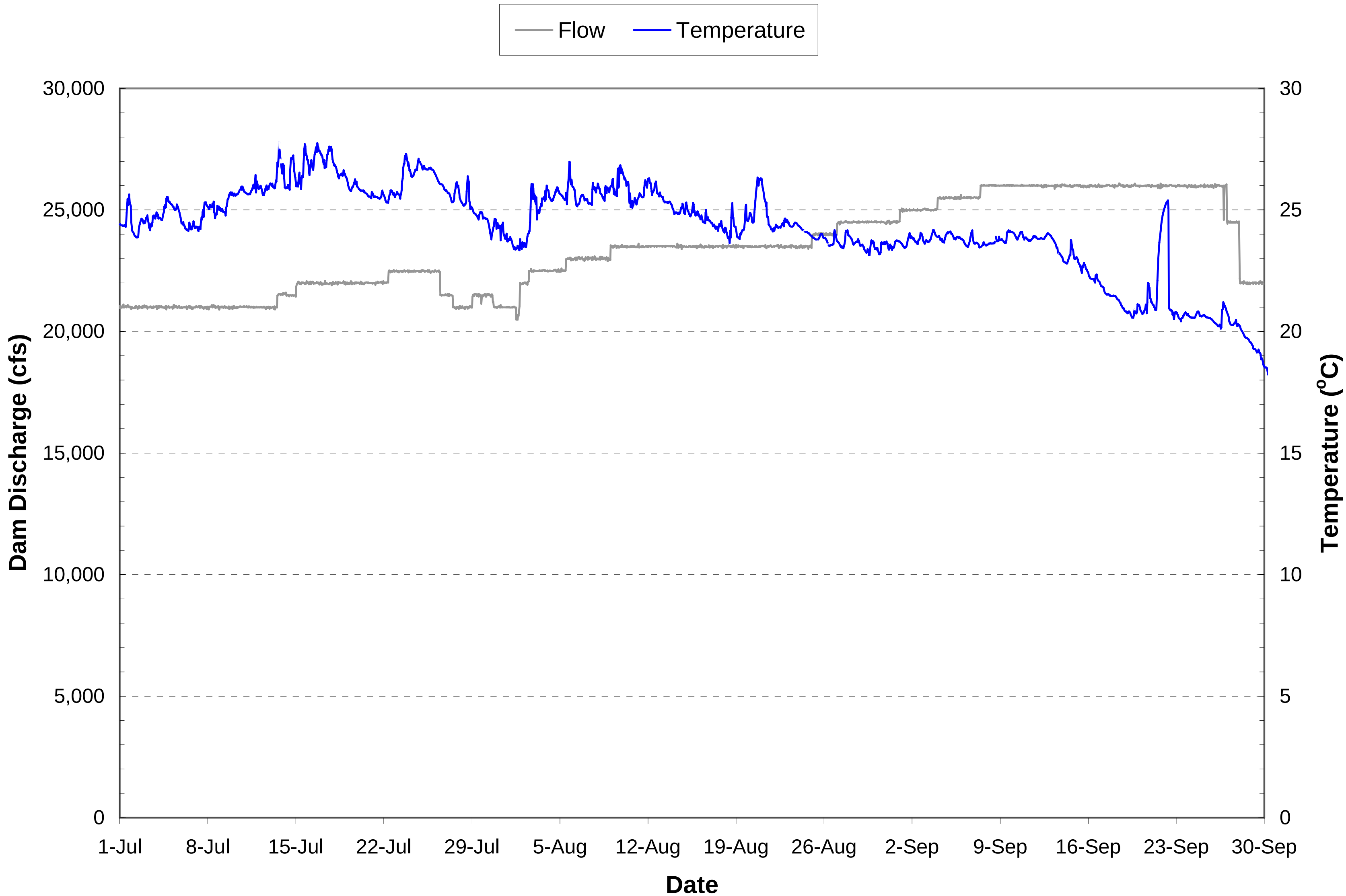


Plate 83. Hourly discharge and water temperature monitored at the Gavins Point power plant on water discharged through the dam during the period July through September 2005.

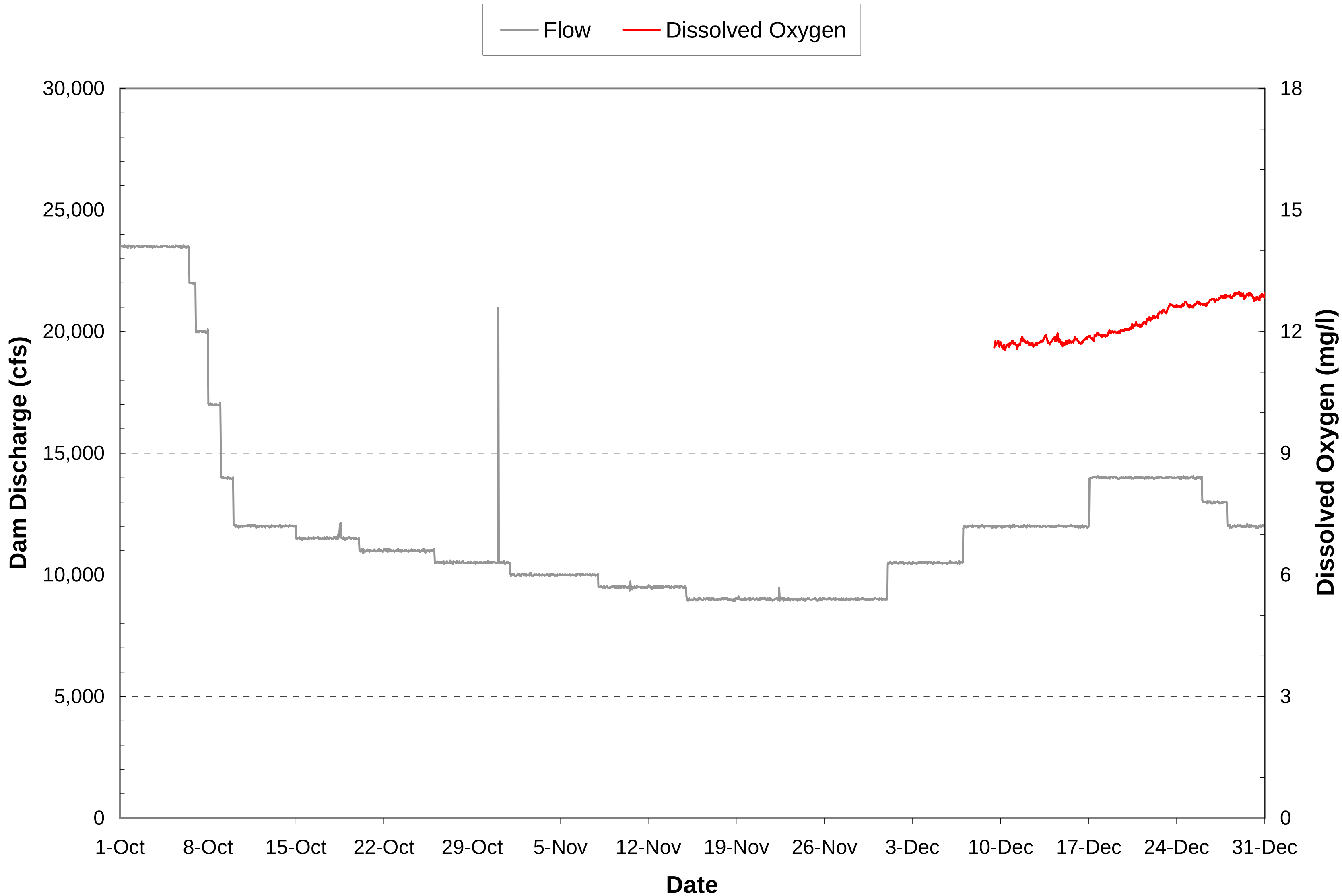


Plate 84. Hourly discharge and dissolved oxygen concentrations monitored at the Gavins Point power plant on water discharged through the dam during the period October through December 2004. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

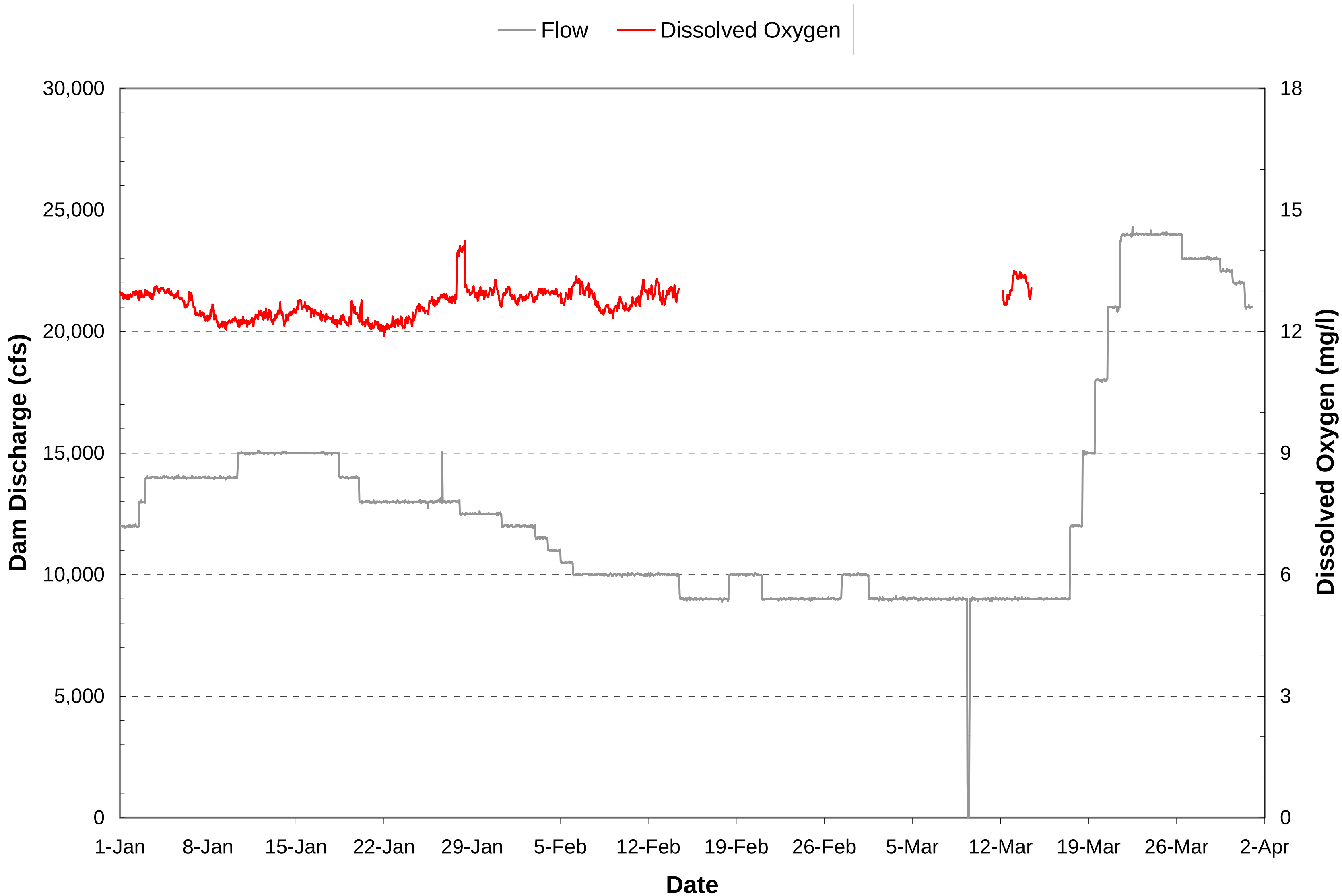


Plate 85. Hourly discharge and dissolved oxygen concentrations monitored at the Gavins Point power plant on water discharged through the dam during the period January through March 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

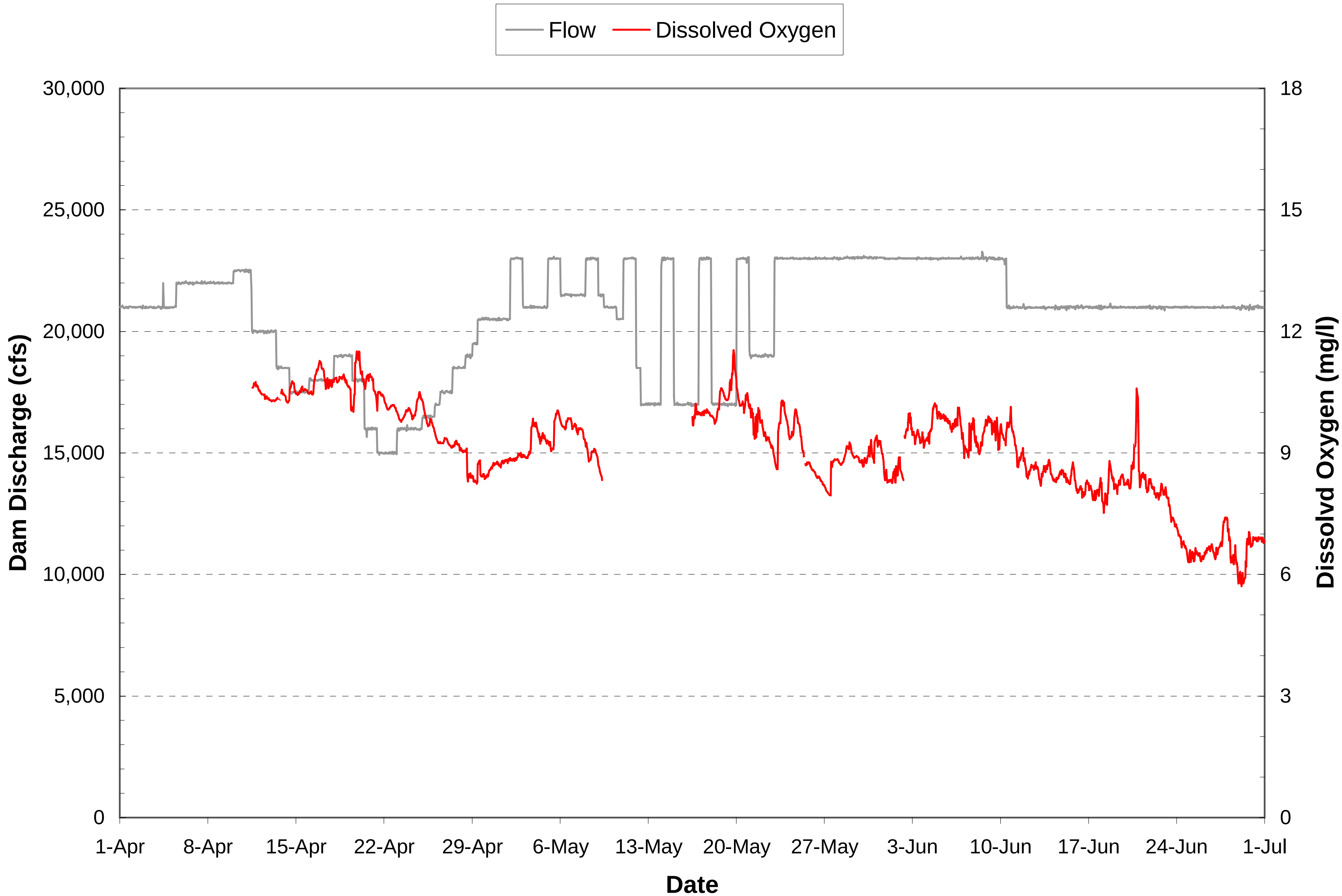


Plate 86. Hourly discharge and dissolved oxygen concentrations monitored at the Gavins Point power plant on water discharged through the dam during the period April through June 2005. (Note gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

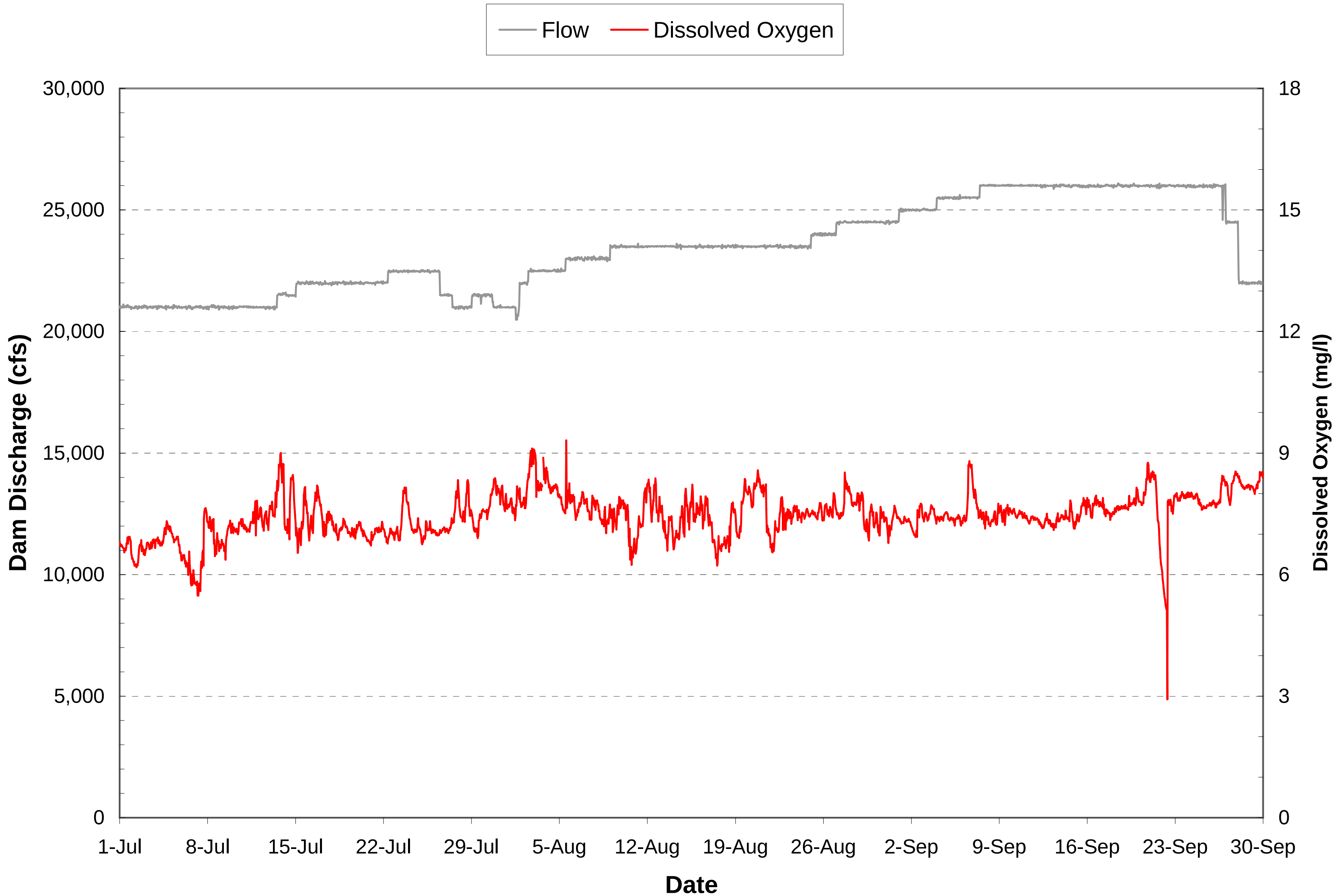


Plate 87. Hourly discharge and dissolved oxygen concentrations monitored at the Gavins Point power plant on water discharged through the dam during the period July through September 2005.

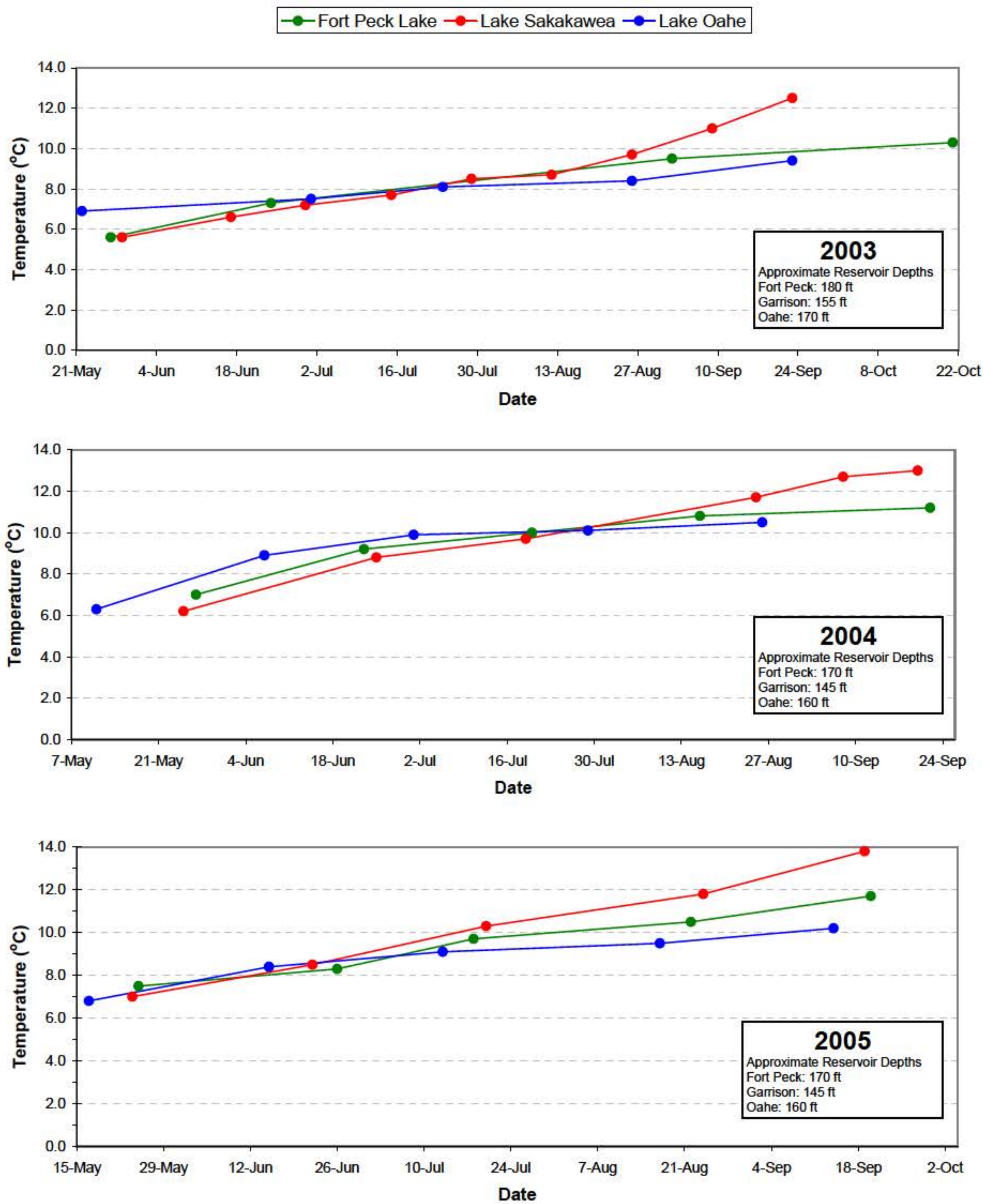


Plate 88. Near-bottom water temperatures measured at near-dam, deepwater locations in Fort Peck, Garrison, and Oahe in 2003, 2004, and 2005.

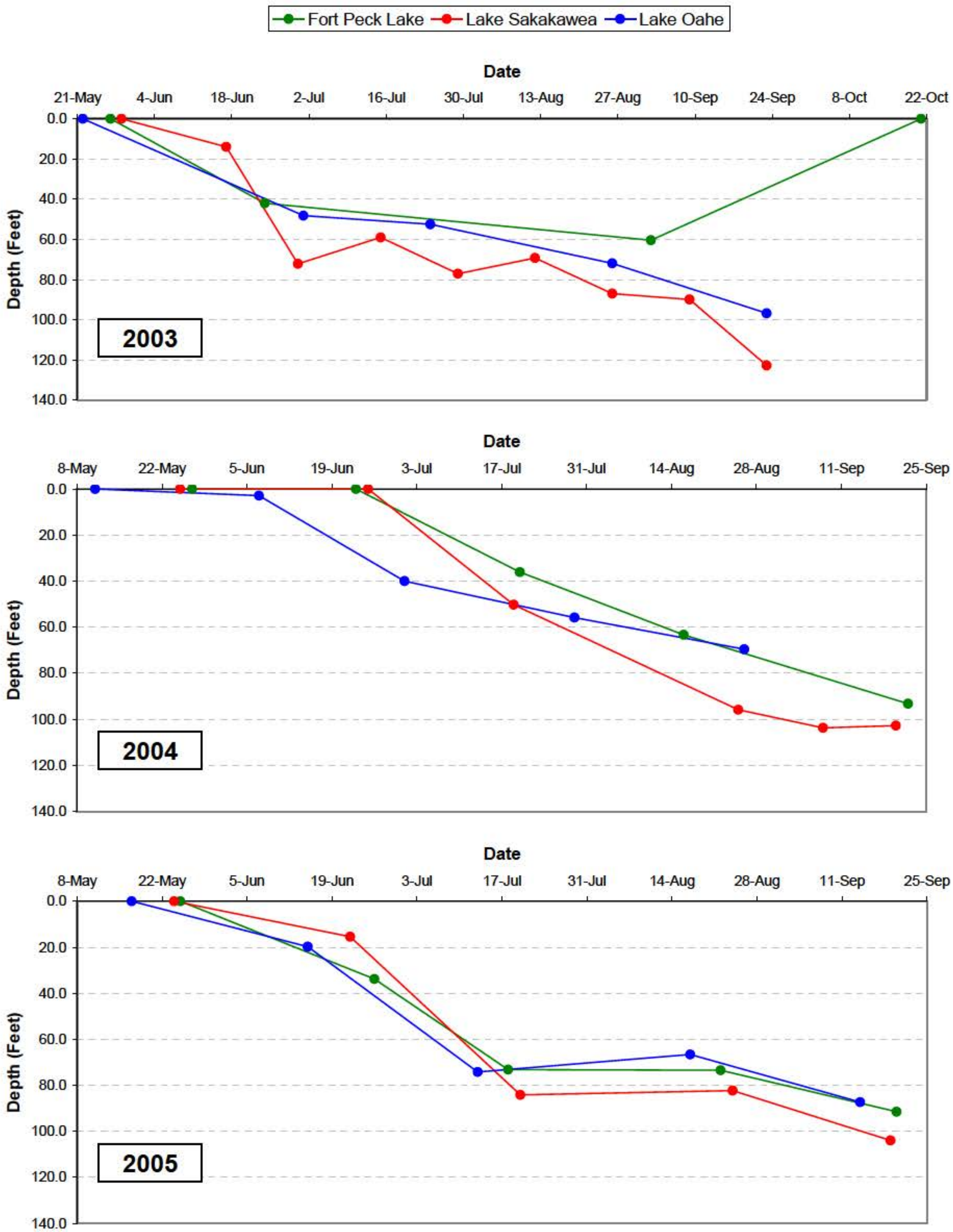


Plate 89. Depth to 15°C water temperature measured at near-dam, deepwater locations in Fort Peck, Garrison, and Oahe Reservoirs in 2003, 2004, and 2005.

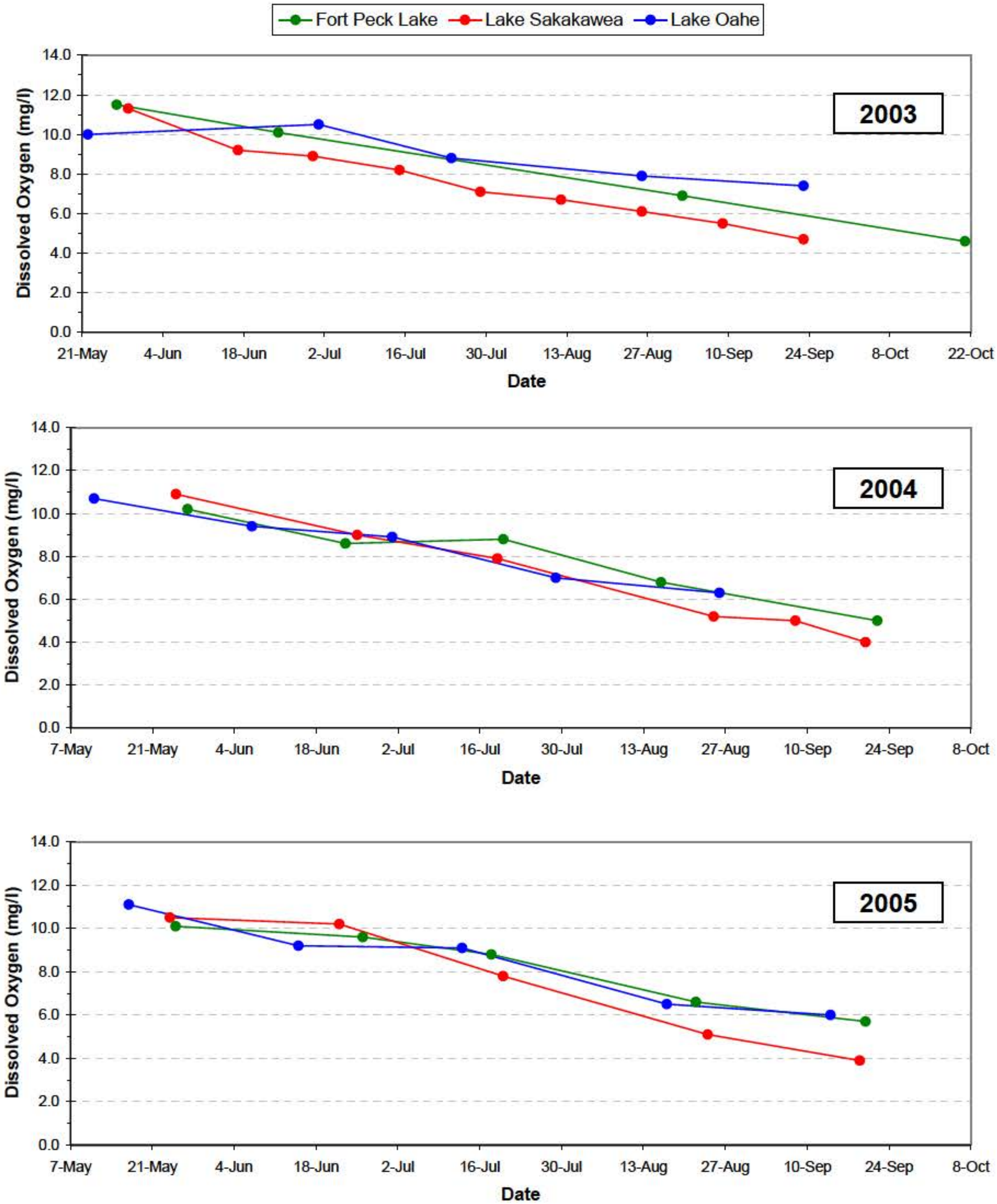


Plate 90. Near-bottom dissolved oxygen concentrations measured at near-dam, deepwater locations in Fort Peck, Garrison, and Oahe Reservoirs in 2003, 2004, and 2005.

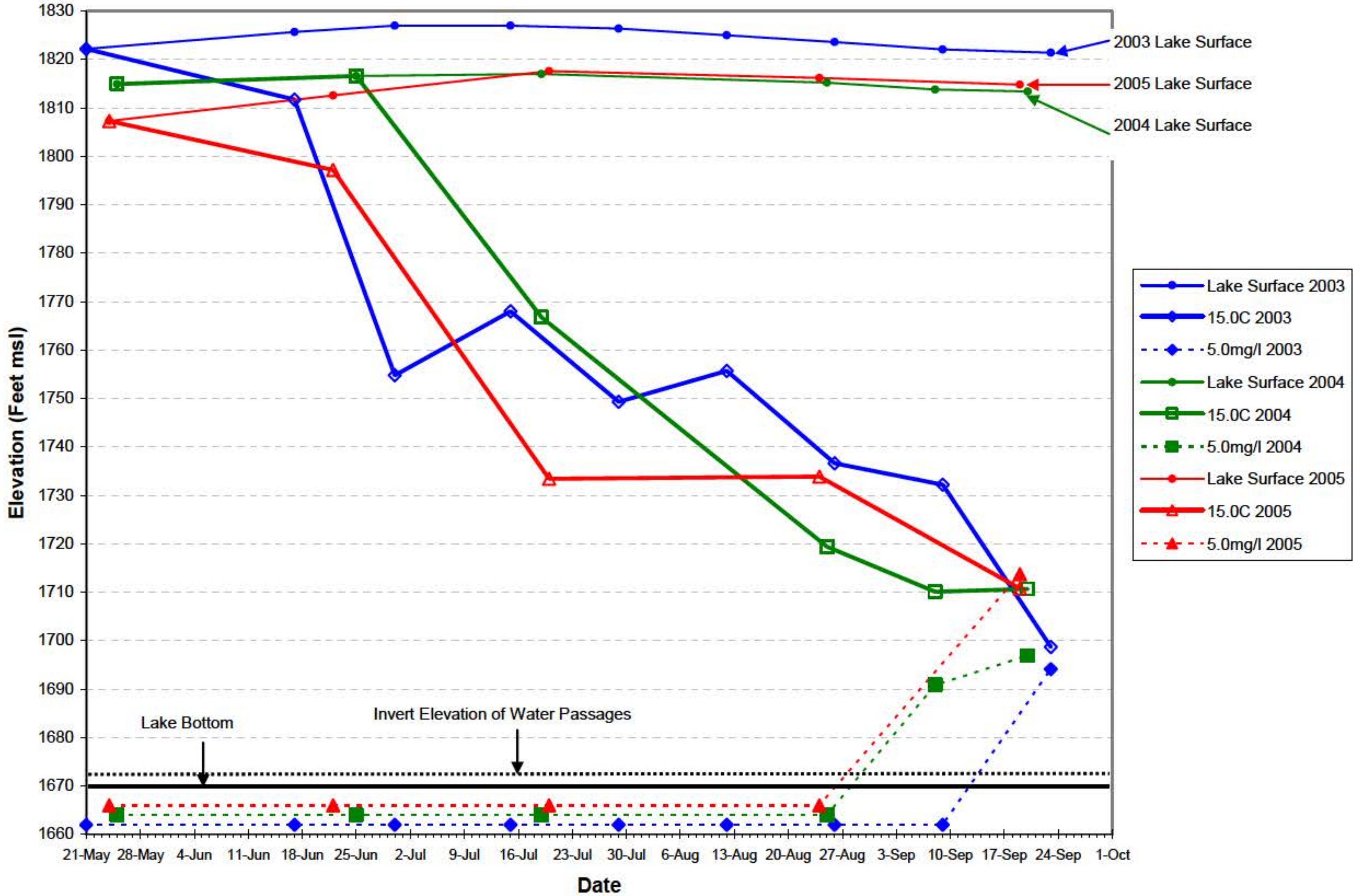


Plate 91. Elevation of the 15°C water temperature and 5 mg/l dissolved oxygen concentration isopleths for Garrison Reservoir based on water quality monitoring conducted at a near-dam, deepwater location during 2003 through 2005. (Also shown are the reservoir surface elevation and the invert elevation of the Garrison Dam power tunnel intake.)

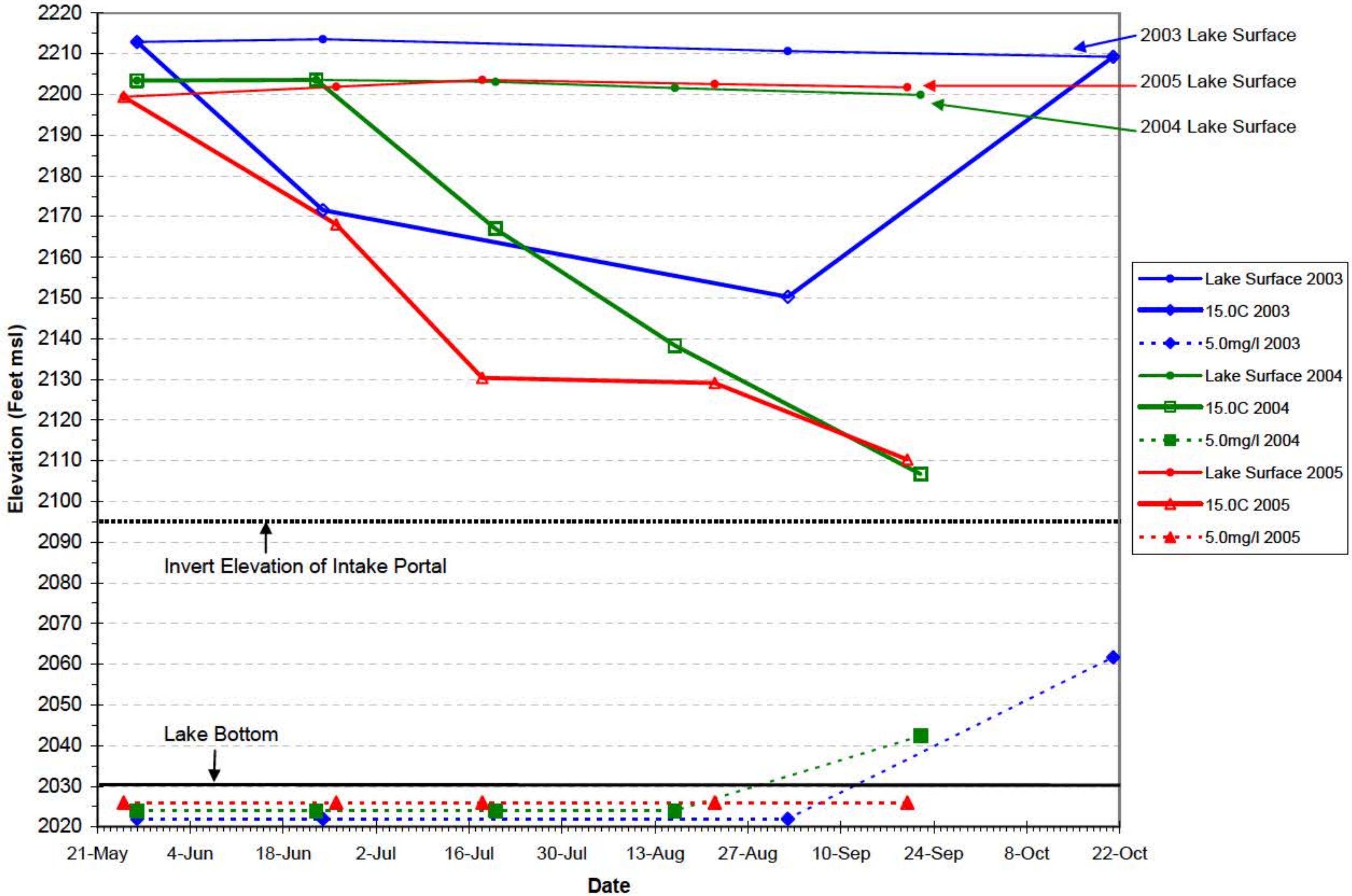


Plate 92. Elevation of the 15°C water temperature and 5 mg/l dissolved oxygen concentration isopleths for Fort Peck Reservoir based on water quality monitoring conducted at a near-dam, deepwater location during 2003 through 2005. (Also shown are the reservoir surface elevation and the invert elevation of the Fort Peck Dam power tunnel intake.)

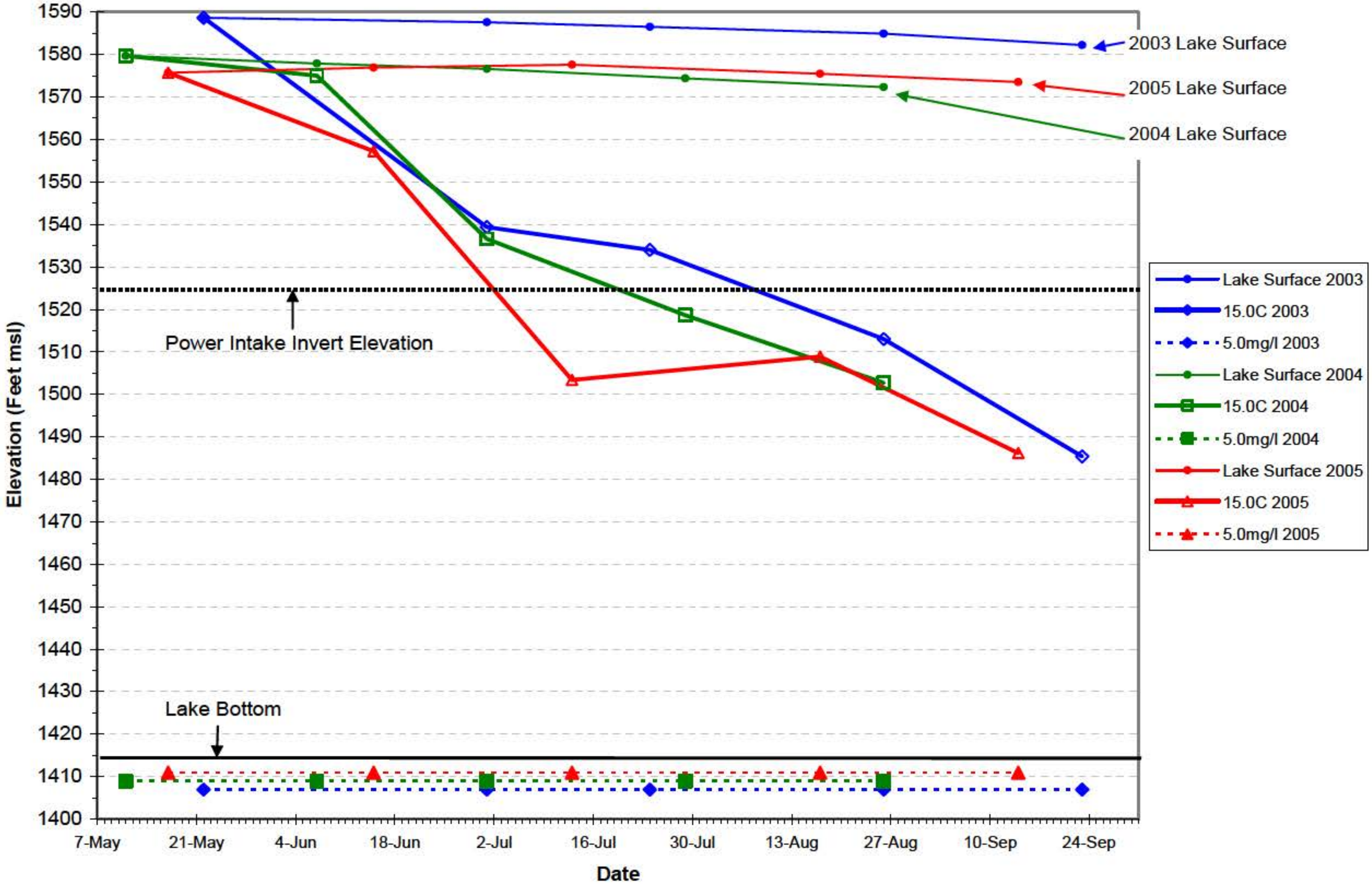


Plate 93. Elevation of the 15°C water temperature and 5 mg/l dissolved oxygen concentration isopleths for Oahe Reservoir based on water quality monitoring conducted at a near-dam, deepwater location during 2003 through 2005. (Also shown are the reservoir surface elevation and the invert elevation of the Oahe Dam power tunnel intake.)

Plate 94. Summary of water quality conditions monitored in the Missouri River at the Fort Randall Dam tailwaters during the 3-year period of April 2003 through September 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	45	26,092	28,200	4,000	40,000	-----	-----	-----
Water Temperature (C)	0.1	45	14.7	16.1	-0.1	24.5	29	0	0%
Dissolved Oxygen (mg/l)	0.1	45	9.3	9.1	4.9	14.8	≥ 5.0	1	2%
Dissolved Oxygen (% Sat.)	0.1	45	92.4	94.0	57.6	111.9	-----	-----	-----
Specific Conductance (umho/cm)	1	45	679	675	535	770	-----	-----	-----
pH (S.U.)	0.1	45	8.3	8.3	7.7	8.7	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	42	177	177	156	223	-----	-----	-----
Ammonia, Total (mg/l)	0.01	42	0.16	0.11	n.d.	1.2	$4.7^{(1,2)}$, $1.3^{(1,3)}$	0	0%
Carbon, Total Organic (mg/l)	0.05	41	3.2	3.2	2.8	3.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	3	42	9	9	4	15	-----	-----	-----
Chloride, Dissolved (mg/l)	1	42	10	10	5	12	-----	-----	-----
Hardness, Total (mg/l)	0.4	9	232	235	217	244	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	42	0.4	0.3	n.d.	2.4	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	42	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	41	0.06	0.03	n.d.	0.6	-----	-----	-----
Suspended Solids, Total (mg/l)	4	42	-----	n.d.	n.d.	13	-----	-----	-----
Turbidity (NTU)	1	45	11	6	2	40	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	9	-----	n.d.	n.d.	n.d.	$340^{(2)}$, $16.7^{(3, 4)}$	0	0%
Cadmium, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	n.d.	$13.5^{(2)}$, $0.5^{(3)}$	0	0%
Chromium, Dissolved (ug/l)	2	9	-----	n.d.	n.d.	n.d.	$1{,}192^{(2)}$, $155^{(3)}$	0	0%
Copper, Dissolved (ug/l)	2	9	-----	n.d.	n.d.	5	$30.1^{(2)}$, $18.6^{(3)}$	0	0%
Lead, Dissolved (ug/l)	2	9	-----	n.d.	n.d.	n.d.	$161^{(2)}$, $6.3^{(3)}$	0	0%
Mercury, Dissolved (ug/l)	0.02	9	-----	n.d.	n.d.	n.d.	$1.4^{(2)}$	0	0%
Mercury, Total (ug/l)	0.02	9	-----	n.d.	n.d.	n.d.	$0.051^{(3, 4)}$	0	0%
Nickel, Dissolved (ug/l)	3	9	-----	n.d.	n.d.	8	$965^{(2)}$, $107^{(3)}$	0	0%
Selenium, Total (ug/l)	4	9	-----	n.d.	n.d.	n.d.	$20^{(2)}$, $5^{(3)}$	0	0%
Silver, Dissolved (ug/l)	1	9	-----	n.d.	n.d.	n.d.	$15.0^{(2)}$	0	0%
Zinc, Dissolved (ug/l)	3	9	-----	n.d.	n.d.	26	$242^{(2,3)}$	0	0%
Alachlor, Total (ug/l)	0.05	40	-----	n.d.	n.d.	n.d.	$760^{(2)}$, $76^{(3)}$	0	0%
Atrazine, Total (ug/l)	0.05	40	-----	n.d.	n.d.	1.26	$330^{(2)}$, $12^{(3)}$	0	0%
Metolachlor, Total (ug/l)	0.05	40	-----	n.d.	n.d.	n.d.	$390^{(2)}$, $100^{(3)}$	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 16.5 respectively.
(2) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
(3) Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
(4) Human health criterion for surface waters.
Note: As appropriate, listed metals criteria were calculated using the median hardness of 235 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 95. Summary of water quality conditions monitored in the Missouri River near Verdel, NE during the 3-year period of April 2003 through September 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	44	25,112	27,874	4,000	40,000	-----	-----	-----
Water Temperature (C)	0.1	44	15.3	16.5	1.7	28.6	29	0	0%
Dissolved Oxygen (mg/l)	0.1	44	9.4	9.1	6.4	13.8	≥ 5.0	0	0%
Dissolved Oxygen (% Sat.)	0.1	44	95.4	95.9	75.0	113.1	-----	-----	-----
Specific Conductance (umho/cm)	1	44	684	679	532	770	-----	-----	-----
pH (S.U.)	0.1	44	8.3	8.3	7.1	9.1	≥6.5 & ≤9.0	1	2%
Alkalinity, Total (mg/l)	7	44	177	175	149	220	-----	-----	-----
Ammonia, Total (mg/l)	0.01	44	-----	0.11	n.d.	1.2	4.7 [1,2], 1.2 [1,3]	0	0%
Carbon, Total Organic (mg/l)	0.05	44	3.1	3.2	2.8	4.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	3	44	8	8	2	15	-----	-----	-----
Chloride, Dissolved (mg/l)	1	43	10	10	5	19	-----	-----	-----
Hardness, Total (mg/l)	0.4	10	230	231	217	244	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	44	0.4	0.4	n.d.	2.4	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	44	-----	n.d.	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	43	0.03	0.02	n.d.	0.12	-----	-----	-----
Suspended Solids, Total (mg/l)	4	44	-----	5	n.d.	19	-----	-----	-----
Turbidity (NTU)	1	44	13	8	3	62	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	n.d.	340[2], 16.7[3, 4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	10	-----	n.d.	n.d.	n.d.	13.3[2], 0.44[3]	0	0%
Chromium, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	1,175[2], 153[3]	0	0%
Copper, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	3	29.6[2], 18.3[3]	0	0%
Lead, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	158[2], 6.2[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	10	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	10	-----	n.d.	n.d.	n.d.	0.051[3, 4]	0	0%
Nickel, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	n.d.	951[2], 106[3]	0	0%
Selenium, Total (ug/l)	4	10	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	10	-----	n.d.	n.d.	n.d.	14.6[2]	0	0%
Zinc, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	8	238[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	42	-----	n.d.	n.d.	n.d.	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	42	-----	n.d.	n.d.	0.27	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)	0.05	42	-----	n.d.	n.d.	0.06	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.5 and 7.8 respectively.
(2) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
(3) Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
(4) Human health criterion for surface waters.
Note: As appropriate, listed metals criteria were calculated using the median hardness of 231 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don’t have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 96. Summary of water quality conditions monitored in the Missouri River at the Gavins Point Dam tailwaters during the 3-year period of April 2003 through September 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	45	22,944	25,000	8,990	30,500	-----	-----	-----
Water Temperature (C)	0.1	45	16.6	19.4	0.6	26.3	29	0	0%
Dissolved Oxygen (mg/l)	0.1	44	9.2	8.7	5.9	14.7	≥ 5.0	1	2%
Dissolved Oxygen (% Sat.)	0.1	44	94.3	93.3	75.6	109.0	-----	-----	-----
Specific Conductance (umho/cm)	1	45	648	649	466	756	-----	-----	-----
pH (S.U.)	0.1	45	8.4	8.4	7.8	9.0	≥6.5 & ≤9.0	1	2%
Alkalinity, Total (mg/l)	7	42	173	171	160	222	-----	-----	-----
Ammonia, Total (mg/l)	0.01	42	0.16	0.11	n.d.	1.30	3 9 [1,2], 0 94 [1,3]	0, 1	0%, 2%
Carbon, Total Organic (mg/l)	0.05	42	3.3	3.2	2.8	7.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	3	41	9	8	4	19	-----	-----	-----
Chloride, Dissolved (mg/l)	1	42	9	10	4	11	-----	-----	-----
Hardness, Total (mg/l)	0.4	9	227	227	211	244	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	42	0.4	0.4	n.d.	2.4	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	42	-----	n.d.	n.d.	0.26	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	41	0.08	0.03	n.d.	1.1	-----	-----	-----
Suspended Solids, Total (mg/l)	4	42	11	11	n.d.	31	-----	-----	-----
Turbidity (NTU)	1	44	23	19	8	64	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	9	-----	n.d.	n.d.	3	340[2], 16.7[3, 4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	n.d.	13.1[2], 0.43[3]	0	0%
Chromium, Dissolved (ug/l)	2	9	-----	n.d.	n.d.	n.d.	1,159[2], 151[3]	0	0%
Copper, Dissolved (ug/l)	2	9	-----	n.d.	n.d.	21	29.1[2], 18.0[3]	0	0%
Lead, Dissolved (ug/l)	2	9	-----	n.d.	n.d.	n.d.	156[2], 6.1[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	9	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	9	-----	n.d.	n.d.	n.d.	0.051[3, 4]	0	0%
Nickel, Dissolved (ug/l)	3	9	-----	n.d.	n.d.	8	937[2], 104[3]	0	0%
Selenium, Total (ug/l)	4	9	-----	n.d.	n.d.	4	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	9	-----	n.d.	n.d.	n.d.	14.1[2]	0	0%
Zinc, Dissolved (ug/l)	3	9	-----	n.d.	n.d.	16	235[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	41	-----	n.d.	n.d.	0.07	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	41	-----	n.d.	n.d.	0.21	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)	0.05	41	-----	n.d.	n.d.	0.13	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.4 and 19.4 respectively.
[2] Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
[3] Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
[4] Human health criterion for surface waters.
Note: As appropriate, listed metals criteria were calculated using the median hardness of 227 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don’t have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 97. Summary of water quality conditions monitored in the Missouri River near Maskell, NE during the 3-year period of April 2003 through September 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	45	23,808	25,160	9,114	30,800	-----	-----	-----
Water Temperature (C)	0.1	45	17.4	20.0	0.5	27.9	29	0	0%
Dissolved Oxygen (mg/l)	0.1	45	9.2	8.7	6.0	14.7	≥ 5.0	0	0%
Dissolved Oxygen (% Sat.)	0.1	45	97.4	97.9	74.5	111.0	-----	-----	-----
Specific Conductance (umho/cm)	1	45	662	664	471	766	-----	-----	-----
pH (S.U.)	0.1	45	8.4	8.4	7.6	9.0	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	45	175	174	135	221	-----	-----	-----
Ammonia, Total (mg/l)	0.01	45	0.19	0.12	n.d.	1.3	3 9 [1,2], 0 94 [1,3]	0, 1	0%, 2%
Carbon, Total Organic (mg/l)	0.05	45	3.3	3.3	2.9	5.2	-----	-----	-----
Chloride, Dissolved (mg/l)	1	44	10	10	4	16	-----	-----	-----
Chemical Oxygen Demand (mg/l)	3	45	10	9	4	27	-----	-----	-----
Hardness, Total (mg/l)	0.4	10	234	235	213	252	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	45	0.5	0.4	n.d.	2.3	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	45	-----	0.03	n.d.	0.46	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	44	0.07	0.05	n.d.	0.37	-----	-----	-----
Suspended Solids, Total (mg/l)	4	45	34	19	8	320	-----	-----	-----
Turbidity (NTU)	1	45	41	24	10	353	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	3	340[2], 16.7[3, 4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	10	-----	n.d.	n.d.	n.d.	13.5[2], 0.5[3]	0	0%
Chromium, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	1,192[2], 155[3]	0	0%
Copper, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	3	30.1[2], 18.6[3]	0	0%
Lead, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	161[2], 6.3[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	10	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	10	-----	n.d.	n.d.	n.d.	0.051[3, 4]	0	0%
Nickel, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	3	965[2], 107[3]	0	0%
Selenium, Total (ug/l)	4	10	-----	n.d.	n.d.	4	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	10	-----	n.d.	n.d.	n.d.	15.0[2]	0	0%
Zinc, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	8	242[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	43	-----	n.d.	n.d.	0.13	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	43	-----	n.d.	n.d.	1.00	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)	0.05	43	-----	n.d.	n.d.	0.41	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.4 and 20.0 respectively.
[2] Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
[3] Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
[4] Human health criterion for surface waters.
Note: As appropriate, listed metals criteria were calculated using the median hardness of 235 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 98. Summary of water quality conditions monitored in the Missouri River near Ponca, NE during the 3-year period of April 2003 through September 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	43	24,047	25,885	9,114	31,600	-----	-----	-----
Water Temperature (C)	0.1	43	17.4	21.0	0.2	28.7	29	0	0%
Dissolved Oxygen (mg/l)	0.1	43	9.2	8.6	7.3	14.2	≥ 5.0	0	0%
Dissolved Oxygen (% Sat.)	0.1	43	98.0	98.9	87.0	116.1	-----	-----	-----
Specific Conductance (umho/cm)	1	43	671	676	475	785	-----	-----	-----
pH (S.U.)	0.1	43	8.4	8.4	7.7	9.0	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	41	175	173	127	218	-----	-----	-----
Ammonia, Total (mg/l)	0.01	41	-----	0.12	n.d.	1.20	3.88[1,2)], 0.85[1,3)]	0, 1	0%, 2%
Carbon, Total Organic (mg/l)	0.05	41	3.5	3.3	2.9	5.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	3	41	13	10	3	56	-----	-----	-----
Chloride, Dissolved (mg/l)	1	41	10	10	5	11	-----	-----	-----
Hardness, Total (mg/l)	0.4	9	236	236	226	246	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	41	0.6	0.5	n.d.	2.3	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	41	-----	n.d.	n.d.	0.32	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	40	0.10	0.05	n.d.	0.73	-----	-----	-----
Suspended Solids, Total (mg/l)	4	41	555	26	9	498	-----	-----	-----
Turbidity (NTU)	1	43	71	26	11	945	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	9	-----	n.d.	n.d.	3	340[(2)], 16.7[(3, 4)]	0	0%
Cadmium, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	n.d.	13.5[(2)], 0.5[(3)]	0	0%
Chromium, Dissolved (ug/l)	2	9	-----	n.d.	n.d.	n.d.	1,192[(2)], 155[(3)]	0	0%
Copper, Dissolved (ug/l)	2	9	-----	n.d.	n.d.	24	30.1[(2)], 18.6[(3)]	0	0%
Lead, Dissolved (ug/l)	2	9	-----	n.d.	n.d.	n.d.	161[(2)], 6.3[(3)]	0	0%
Mercury, Dissolved (ug/l)	0.02	9	-----	n.d.	n.d.	n.d.	1.4[(2)]	0	0%
Mercury, Total (ug/l)	0.02	9	-----	n.d.	n.d.	n.d.	0.051[(3, 4)]	0	0%
Nickel, Dissolved (ug/l)	3	9	-----	n.d.	n.d.	n.d.	965[(2)], 107[(3)]	0	0%
Selenium, Total (ug/l)	4	9	-----	n.d.	n.d.	n.d.	20[(2)], 5[(3)]	0	0%
Silver, Dissolved (ug/l)	1	8	-----	n.d.	n.d.	1	15.0[(2)]	0	0%
Zinc, Dissolved (ug/l)	3	9	-----	n.d.	n.d.	29	242[(2,3)]	0	0%
Alachlor, Total (ug/l)	0.05	40	-----	n.d.	n.d.	0.09	760[(2)], 76[(3)]	0	0%
Atrazine, Total (ug/l)	0.05	40	-----	0.09	n.d.	1.47	330[(2)], 12[(3)]	0	0%
Metolachlor, Total (ug/l)	0.05	40	-----	n.d.	n.d.	0.70	390[(2)], 100[(3)]	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.4 and 21.0 respectively.
(2) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
(3) Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
(4) Human health criterion for surface waters.
Note: As appropriate, listed metals criteria were calculated using the median hardness of 236mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 99. Summary of water quality conditions monitored in the Missouri River at Decatur, NE during the 3-year period of April 2003 through September 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	47	26,706	27,500	11,500	42,400	-----	-----	-----
Water Temperature (C)	0.1	47	17.9	21.0	-0.1	27.4	32	0	0%
Dissolved Oxygen (mg/l)	0.1	47	9.0	8.2	6.4	14.9	≥ 5.0	0	0%
Dissolved Oxygen (% Sat.)	0.1	47	95.8	96.5	79.6	110.7	-----	-----	-----
Specific Conductance (umho/cm)	1	47	701	699	509	800	-----	-----	-----
pH (S.U.)	0.1	47	8.3	8.3	7.2	8.9	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	46	182	182	140	222	-----	-----	-----
Ammonia, Total (mg/l)	0.01	46	0.22	0.14	n.d.	1.30	4.71[1,2], 1.00[1,3]	0, 1	0%, 2%
Carbon, Total Organic (mg/l)	0.05	45	3.5	3.5	2.2	6.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	3	46	13	11	6	40	-----	-----	-----
Chloride, Dissolved (mg/l)	1	46	13	13	8	19	-----	-----	-----
Hardness, Total (mg/l)	0.4	10	256	257	232	278	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	46	0.7	0.6	n.d.	2.2	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	46	0.69	0.56	n.d.	2.80	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	45	0.16	0.10	n.d.	0.87	-----	-----	-----
Suspended Solids, Total (mg/l)	4	46	83	41	6	455	-----	-----	-----
Turbidity (NTU)	1	45	81	41	11	397	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	5	340[2], 16.7[3, 4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	10	-----	n.d.	n.d.	n.d.	14.8[2], 0.5[3]	0	0%
Chromium, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	2	1,283[2], 167[3]	0	0%
Copper, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	32.7[2], 20.1[3]	0	0%
Lead, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	177[2], 6.9[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	10	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	10	-----	n.d.	n.d.	n.d.	0.051[3, 4]	0	0%
Nickel, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	n.d.	1,041[2], 116[3]	0	0%
Selenium, Total (ug/l)	4	10	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	10	-----	n.d.	n.d.	2	17.5[2]	0	0%
Zinc, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	15	261[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	44	-----	n.d.	n.d.	0.43	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	44	-----	0.12	n.d.	2.05	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)	0.05	44	-----	n.d.	n.d.	0.68	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 21.0 respectively.
[2] Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
[3] Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
[4] Human health criterion for surface waters.
Note: As appropriate, listed metals criteria were calculated using the median hardness of 257mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 100. Summary of water quality conditions monitored in the Missouri River at Omaha, NE during the 3-year period of April 2003 through September 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	48	28,997	29,300	14,599	48,200	-----	-----	-----
Water Temperature (C)	0.1	48	17.7	20.6	-0.1	28.1	32	0	0%
Dissolved Oxygen (mg/l)	0.1	48	8.8	8.1	5.9	15.0	≥ 5.0	0	0%
Dissolved Oxygen (% Sat.)	0.1	48	92.5	93.8	68.6	120.7	-----	-----	-----
Specific Conductance (umho/cm)	1	48	688	689	520	786	-----	-----	-----
pH (S.U.)	0.1	48	8.2	8.3	6.9	8.9	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	46	179	180	81	240	-----	-----	-----
Ammonia, Total (mg/l)	0.01	46	0.24	0.12	n.d.	1.4	4.71(1,2), 1.03(1,3)	0, 1	0%, 2%
Carbon, Total Organic (mg/l)	0.05	46	3.6	3.5	2.9	5.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	3	46	18	12	4	141	-----	-----	-----
Chloride, Dissolved (mg/l)	1	46	15	13	7	84	-----	-----	-----
Hardness, Total (mg/l)	0.4	10	263	263	237	295	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	46	1.0	0.7	0.1	4.5	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	46	1.22	1.20	0.03	4.00	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	45	0.30	0.16	0.03	2.30	-----	-----	-----
Suspended Solids, Total (mg/l)	4	46	203	79	13	1,932	-----	-----	-----
Turbidity (NTU)	1	47	193	77	17	1,798	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	5	340(2), 16.7(3, 4)	0	0%
Cadmium, Dissolved (ug/l)	0.5	10	-----	n.d.	n.d.	n.d.	15.1(2), 0.5(3)	0	0%
Chromium, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	1,307(2), 170(3)	0	0%
Copper, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	33.4(2), 20.5(3)	0	0%
Lead, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	182(2), 7.1(3)	0	0%
Mercury, Dissolved (ug/l)	0.02	10	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	10	-----	n.d.	n.d.	0.02	0.051(3, 4)	0	0%
Nickel, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	n.d.	1,061(2), 118(3)	0	0%
Selenium, Total (ug/l)	4	10	-----	n.d.	n.d.	4	20(2), 5(3)	0	0%
Silver, Dissolved (ug/l)	1	10	-----	n.d.	n.d.	1	18.2(2)	0	0%
Zinc, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	4	266(2,3)	0	0%
Alachlor, Total (ug/l)	0.05	44	-----	n.d.	n.d.	0.34	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)	0.05	44	-----	0.13	n.d.	16.20	330(2), 12(3)	0, 1	0%, 2%
Metolachlor, Total (ug/l)	0.05	44	-----	n.d.	n.d.	2.64	390(2), 100(3)	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 20.6 respectively.
(2) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
(3) Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
(4) Human health criterion for surface waters.
Note: As appropriate, listed metals criteria were calculated using the median hardness of 263mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 101. Summary of water quality conditions monitored in the Missouri River at Nebraska City, NE during the 3-year period of April 2003 through September 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	48	34,178	33,250	16,800	57,600	-----	-----	-----
Water Temperature (C)	0.1	48	18.2	21.0	-0.1	29.2	32	0	0%
Dissolved Oxygen (mg/l)	0 1	48	8.4	7.6	5.4	14.0	≥ 5.0	0	0%
Dissolved Oxygen (% Sat.)	0.1	48	89.0	89.3	67.3	104.8	-----	-----	-----
Specific Conductance (umho/cm)	1	48	677	677	516	803	-----	-----	-----
pH (S.U.)	0.1	48	8.2	8.3	7.4	8.8	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	46	177	180	104	228	-----	-----	-----
Ammonia, Total (mg/l)	0.01	46	0.24	0.14	n.d.	1 3	4.71$^{1,2)}$, 1.00$^{1,3)}$	0, 1	0%, 2%
Carbon, Total Organic (mg/l)	0.05	46	3.8	3.7	2.9	5.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	3	46	21	15	7	134	-----	-----	-----
Chloride, Dissolved (mg/l)	1	46	21	20	10	39	-----	-----	-----
Hardness, Total (mg/l)	0.4	10	255	252	229	282	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	46	0.2	0.9	0.1	4.5	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	46	1.29	1.40	0.11	3.30	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	45	0.41	0.23	0.07	2.90	-----	-----	-----
Suspended Solids, Total (mg/l)	4	46	251	111	13	1,952	-----	-----	-----
Turbidity (NTU)	1	47	251	96	21	2,009	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	6	340$^{(2)}$, 16.7$^{(3, 4)}$	0	0%
Cadmium, Dissolved (ug/l)	0 5	10	-----	n.d.	n.d.	n.d.	14.5$^{(2)}$, 0.5$^{(3)}$	0	0%
Chromium, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	2	1,262$^{(2)}$, 164$^{(3)}$	0	0%
Copper, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	2	32.1$^{(2)}$, 19.7$^{(3)}$	0	0%
Lead, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	174$^{(2)}$, 6.8$^{(3)}$	0	0%
Mercury, Dissolved (ug/l)	0.02	10	-----	n.d.	n.d.	n.d.	1.4$^{(2)}$	0	0%
Mercury, Total (ug/l)	0.02	10	-----	n.d.	n.d.	0.03	0.051$^{(3, 4)}$	0	0%
Nickel, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	3	1,023$^{(2)}$, 114$^{(3)}$	0	0%
Selenium, Total (ug/l)	4	10	-----	n.d.	n.d.	4	20$^{(2)}$, 5$^{(3)}$	0	0%
Silver, Dissolved (ug/l)	1	10	-----	n.d.	n.d.	2	16.9$^{(2)}$	0	0%
Zinc, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	9	256$^{(2,3)}$	0	0%
Alachlor, Total (ug/l)	0.05	44	-----	n.d.	n.d.	0.26	760$^{(2)}$, 76$^{(3)}$	0	0%
Atrazine, Total (ug/l)	0.05	44	0.94	0.21	n.d.	13.20	330$^{(2)}$, 12$^{(3)}$	0, 1	0%, 2%
Metolachlor, Total (ug/l)	0.05	44	-----	0.06	n.d.	2.34	390$^{(2)}$, 100$^{(3)}$	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.****	n.d.	n.d.****	*****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i e., log conversion of logarithmic pH values was not done to calculate mean).

** $^{(1)}$ Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 21.0 respectively.
$^{(2)}$ Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
$^{(3)}$ Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
$^{(4)}$Human health criterion for surface waters.
Note: As appropriate, listed metals criteria were calculated using the median hardness of 252 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Acetochlor was detected and had a median value of 0.20 and a maximum value of 0.54.

***** Some pesticides don’t have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 102. Summary of water quality conditions monitored in the Missouri River at Rulo, NE during the 3-year period of April 2003 through September 2005.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	48	35,871	33,900	18,500	72,700	-----	-----	-----
Water Temperature (C)	0.1	48	19.0	21.3	-0.1	30.6	32	0	0%
Dissolved Oxygen (mg/l)	0 1	48	8 3	7.6	5.0	14.6	≥ 5.0	0	0%
Dissolved Oxygen (% Sat.)	0.1	48	89.9	90.3	66.0	111.8	-----	-----	-----
Specific Conductance (umho/cm)	1	48	671	673	534	788	-----	-----	-----
pH (S.U.)	0.1	48	8.2	8.3	7.4	8.8	≥6.5 & ≤9.0	0	0%
Alkalinity, Total (mg/l)	7	46	175	174	105	242	-----	-----	-----
Ammonia, Total (mg/l)	0.01	46	0.25	0.16	n.d.	1.20	4.71[1,2)], 0.98[1,3)]	0, 1	0%, 2%
Carbon, Total Organic (mg/l)	0.05	46	3.6	3.5	2.3	5.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	3	46	20	15	4	114	-----	-----	-----
Chloride, Dissolved (mg/l)	1	46	20	19	10	32	-----	-----	-----
Hardness, Total (mg/l)	0.4	10	254	254	231	289	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	46	1.2	1.0	0.4	5.4	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	46	1.50	1.50	0.06	3.90	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	45	0.38	0.27	0.08	1.70	-----	-----	-----
Suspended Solids, Total (mg/l)	4	46	237	128	20	1,656	-----	-----	-----
Turbidity (NTU)	1	47	2223	96	23	1,512	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	7	340[(2)], 16.7[(3, 4)]	0	0%
Cadmium, Dissolved (ug/l)	0 5	10	-----	n.d.	n.d.	n.d.	14.5[(2)], 0.5[(3)]	0	0%
Chromium, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	2	1,262[(2)], 164[(3)]	0	0%
Copper, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	3	32.1[(2)], 19.7[(3)]	0	0%
Lead, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	174[(2)], 6.8[(3)]	0	0%
Mercury, Dissolved (ug/l)	0.02	10	-----	n.d.	n.d.	n.d.	1.4[(2)]	0	0%
Mercury, Total (ug/l)	0.02	10	-----	n.d.	n.d.	0.02	0.051[(3, 4)]	0	0%
Nickel, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	n.d.	1,023[(2)], 114[(3)]	0	0%
Selenium, Total (ug/l)	4	10	-----	n.d.	n.d.	6	20[(2)], 5[(3)]	0	0%
Silver, Dissolved (ug/l)	1	10	-----	n.d.	n.d.	2	16.9[(2)]	0	0%
Zinc, Dissolved (ug/l)	3	10	-----	n.d.	n.d.	10	256[(2,3)]	0	0%
Alachlor, Total (ug/l)	0.05	44	-----	n.d.	n.d.	0.23	760[(2)], 76[(3)]	0	0%
Atrazine, Total (ug/l)	0.05	44	0.64	0.22	n.d.	4.36	330[(2)], 12[(3)]	0	0%
Metolachlor, Total (ug/l)	0.05	44	-----	0.03	n.d.	2.01	390[(2)], 100[(3)]	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.****	n.d.	n.d.****	*****	0	0%

n.d. = Not detected.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i e., log conversion of logarithmic pH values was not done to calculate mean).

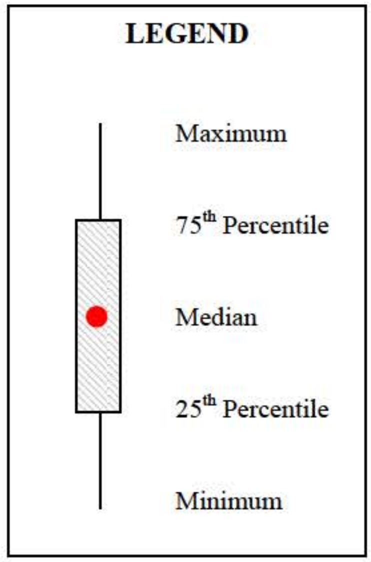
** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 21.0 respectively.
(2) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
(3) Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
(4) Human health criterion for surface waters.
Note: As appropriate, listed metals criteria were calculated using the median hardness of 252 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Acetochlor was detected and had a median value of n.d. and a maximum value of 0.10.

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 103. Distribution plots (i.e., box plots) for selected parameters monitored at locations along the Missouri River from Fort Randall Dam, South Dakota to Rulo, Nebraska during the 3-year period of 2003 through 2005.



Note: Monitoring location refers to the River Mile (RM) along the Missouri River where the monitoring site was located.

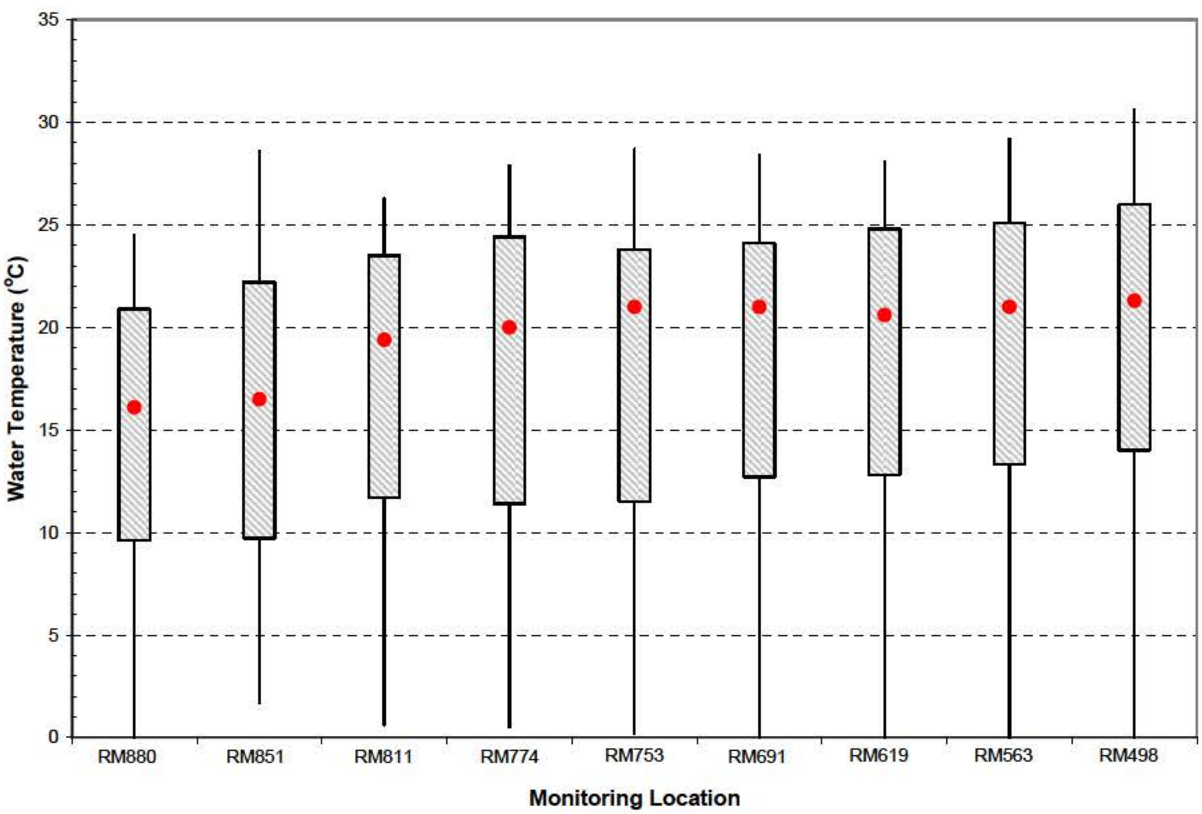
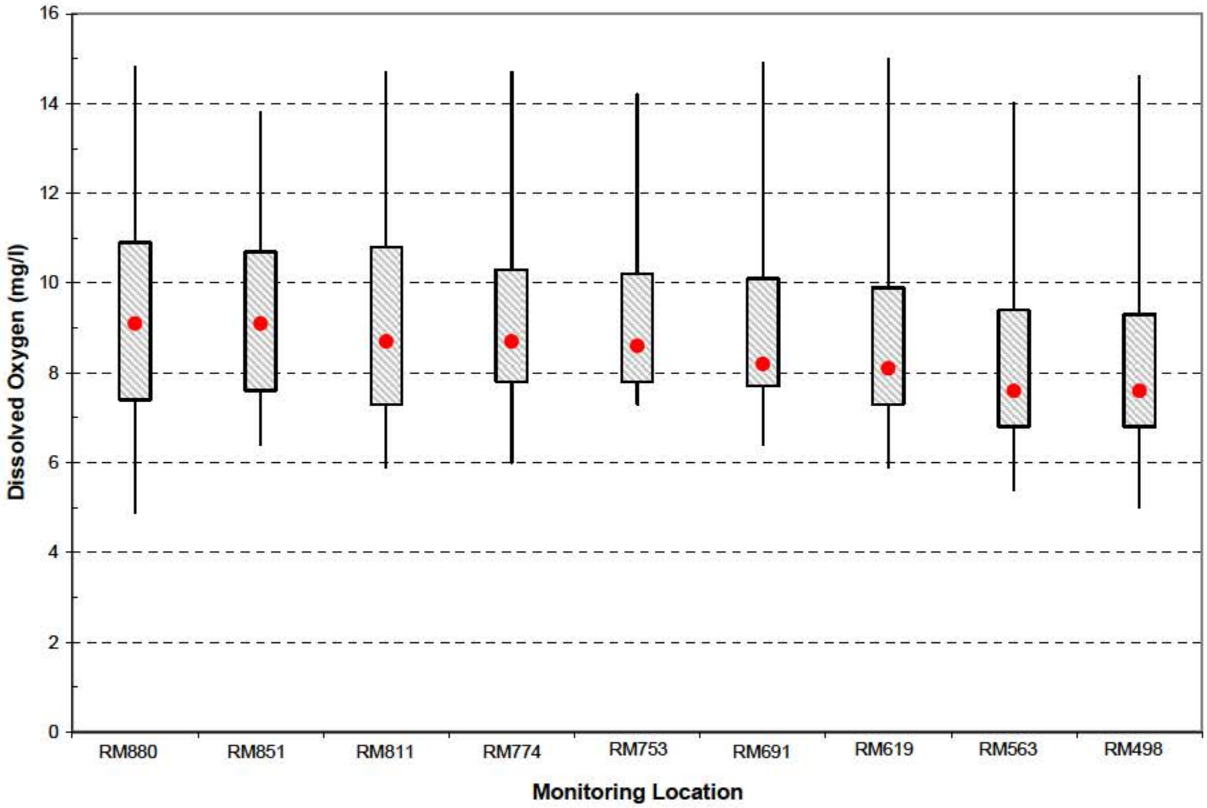


Plate I-103. (Continued).



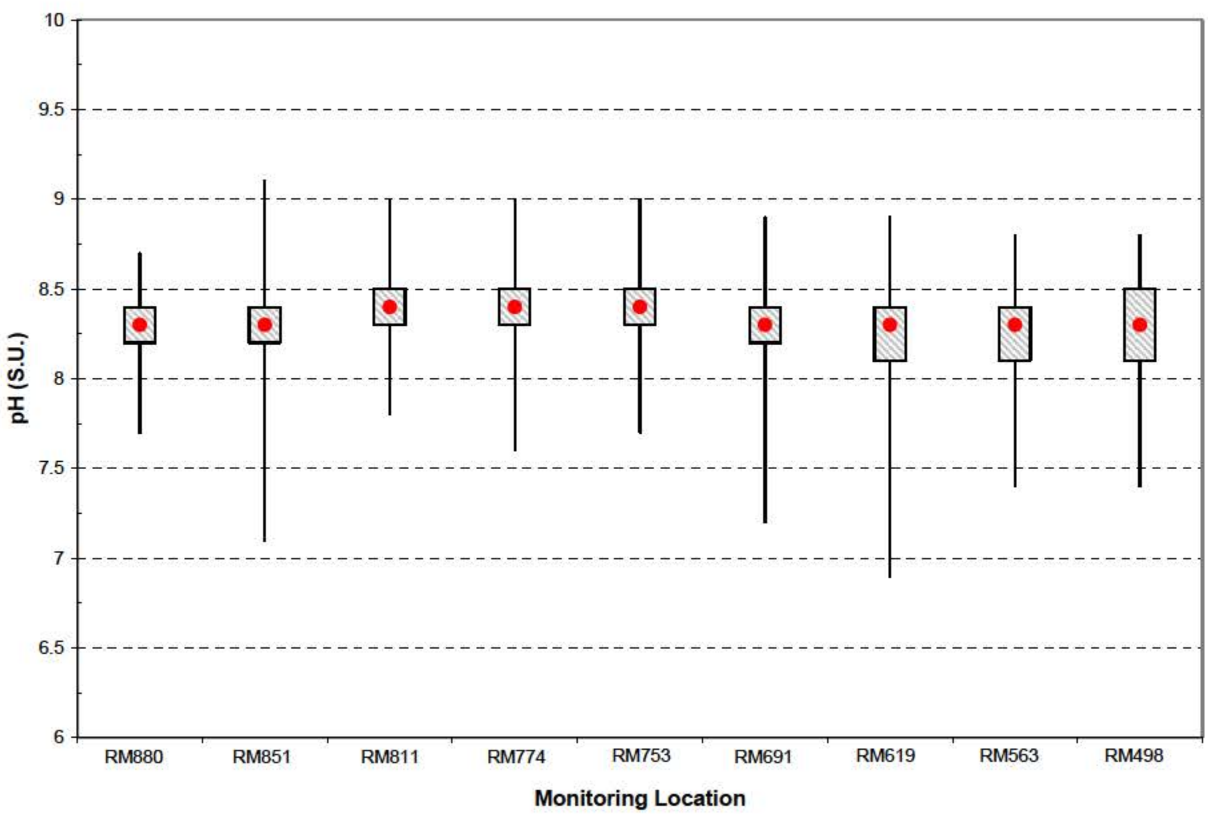
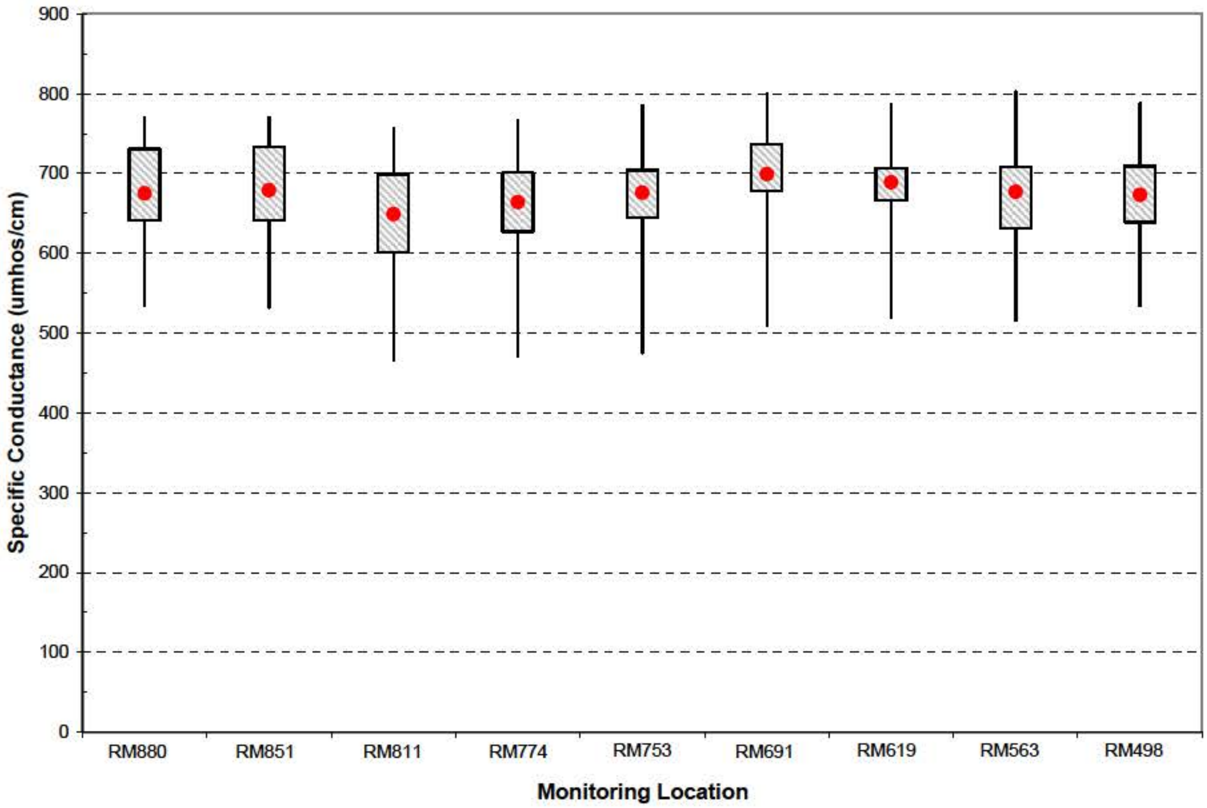


Plate I-103. (Continued).



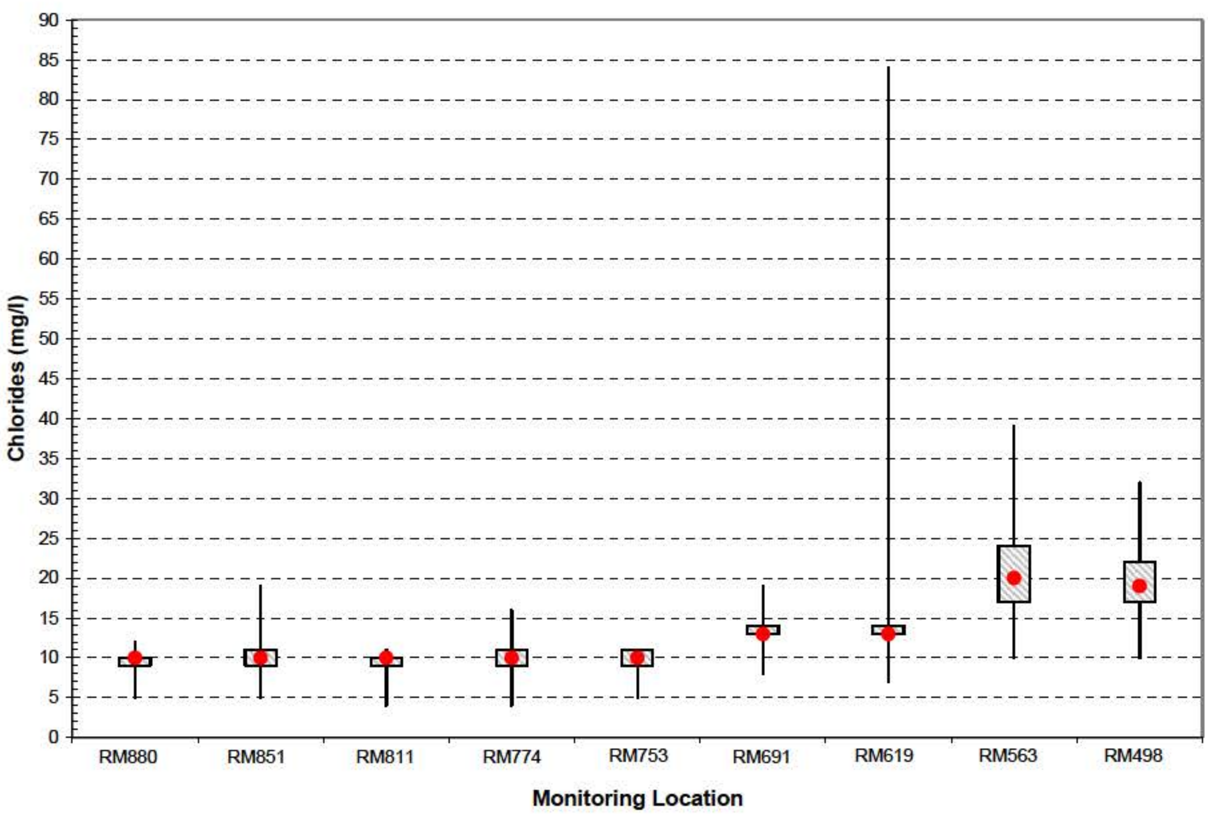
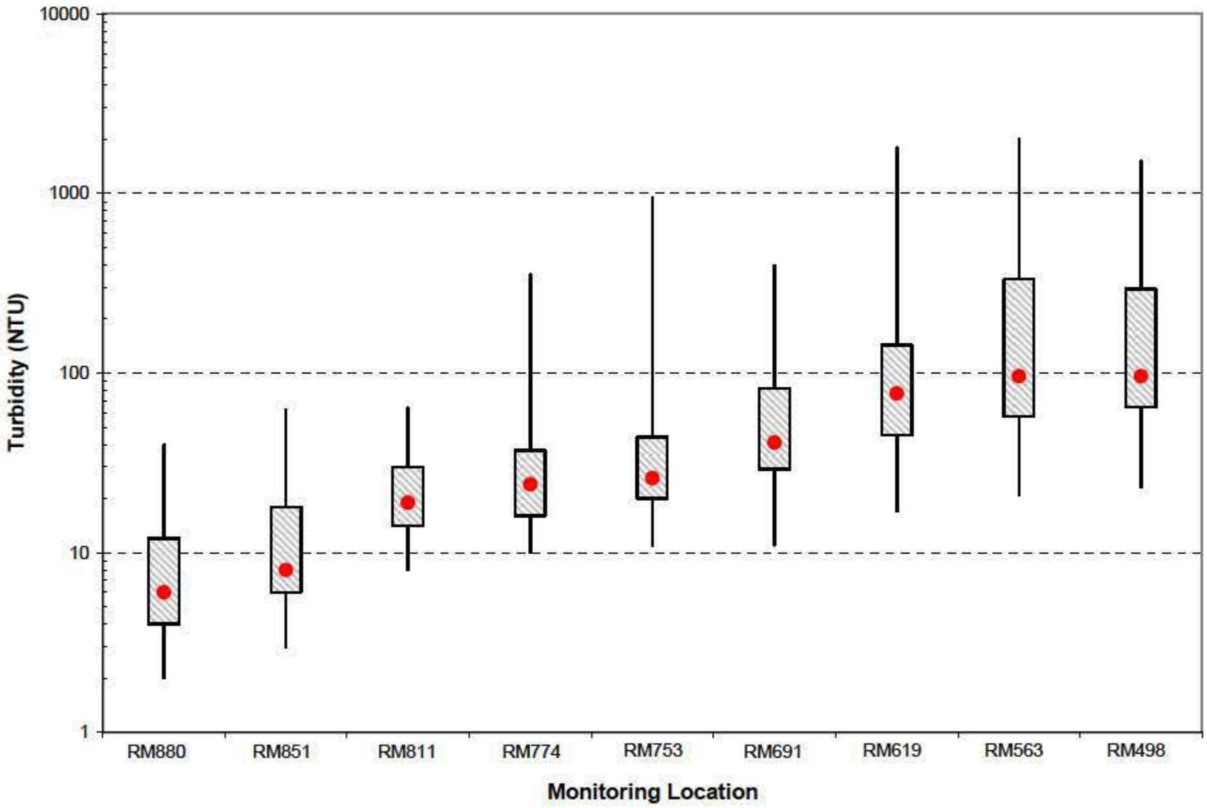


Plate I-103. (Continued).



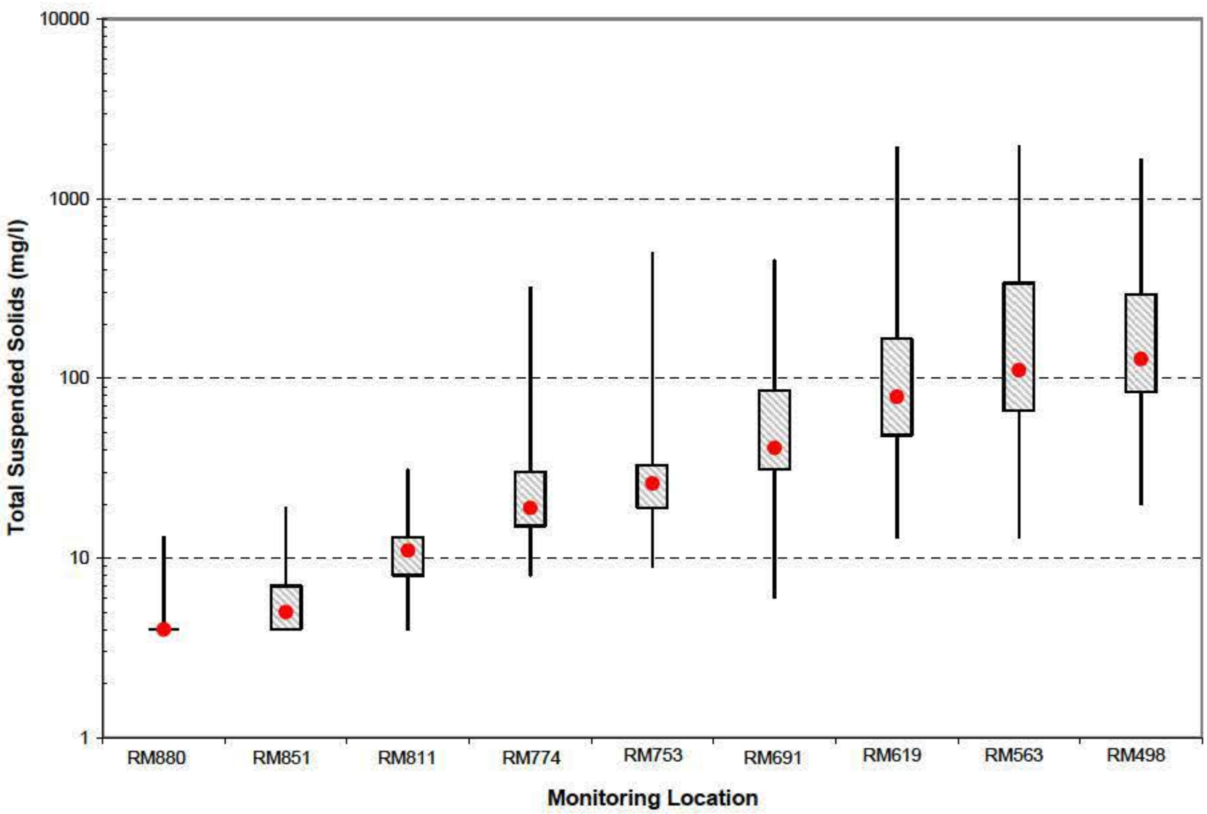
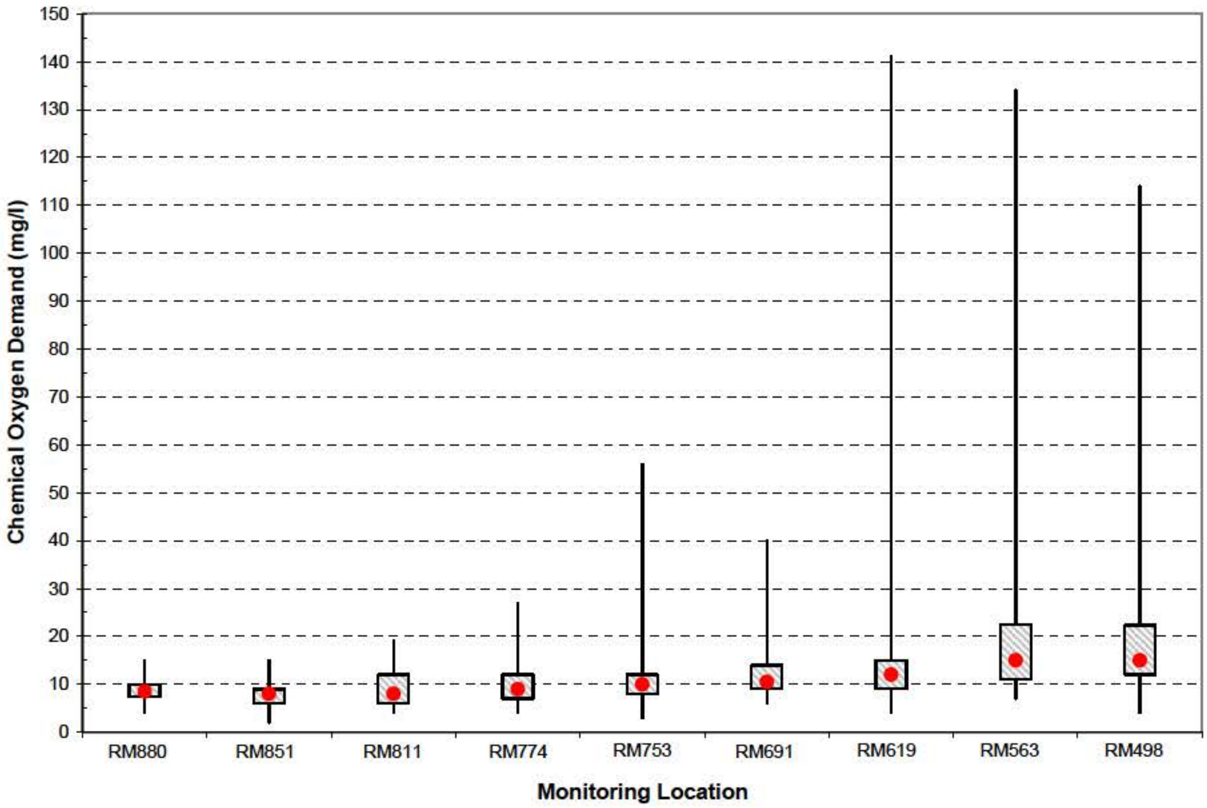


Plate I-103. (Continued).



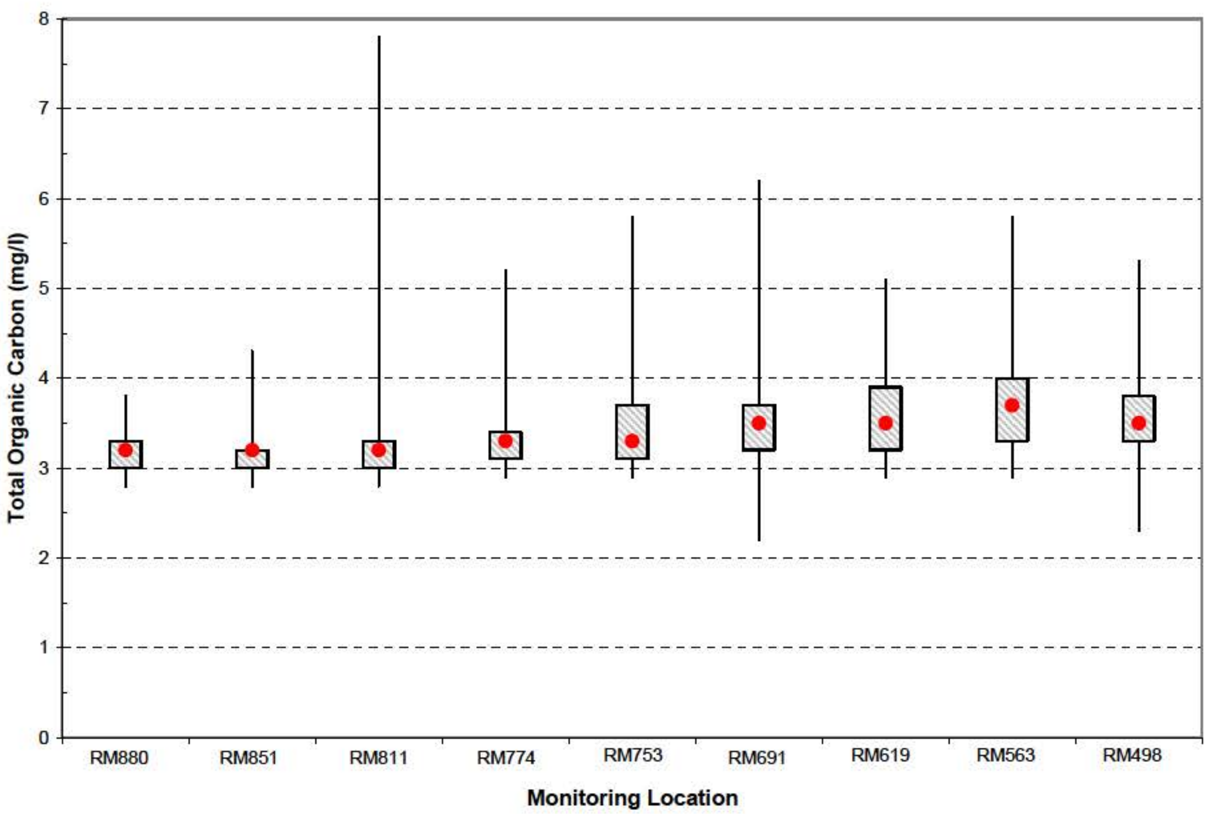
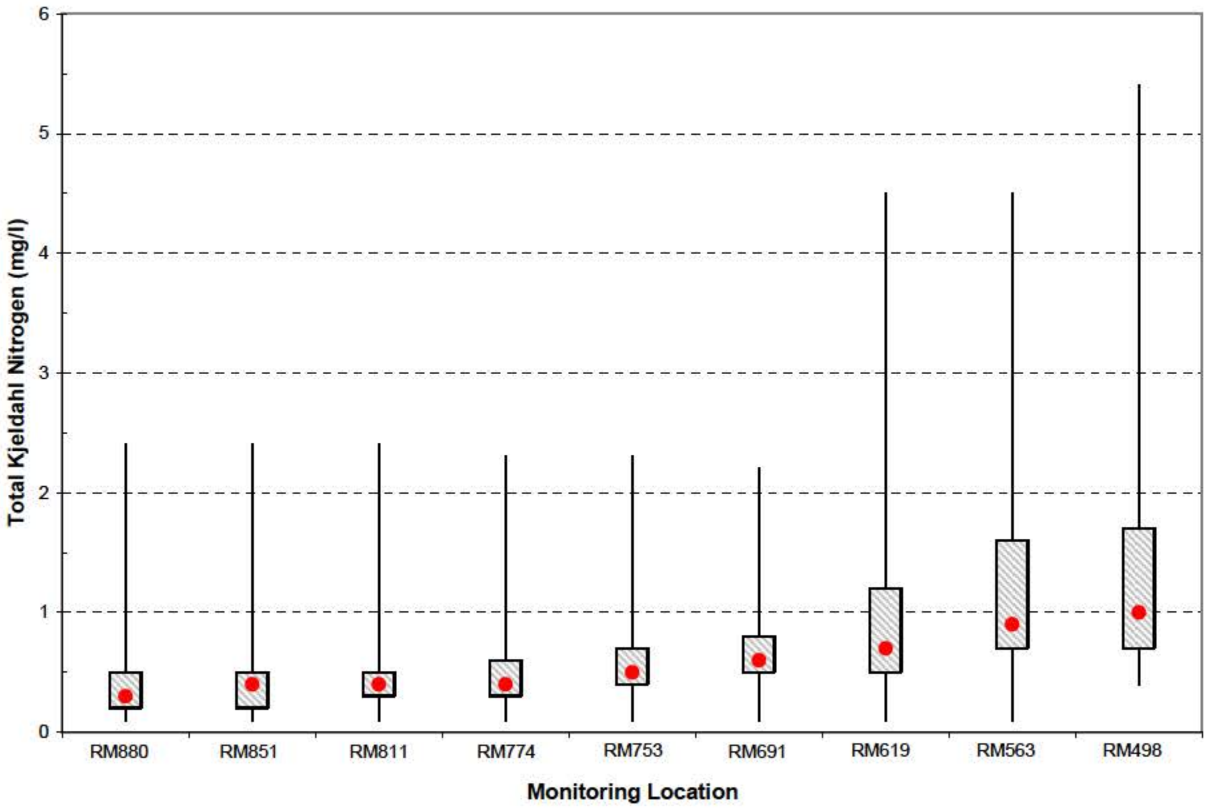


Plate I-103. (Continued).



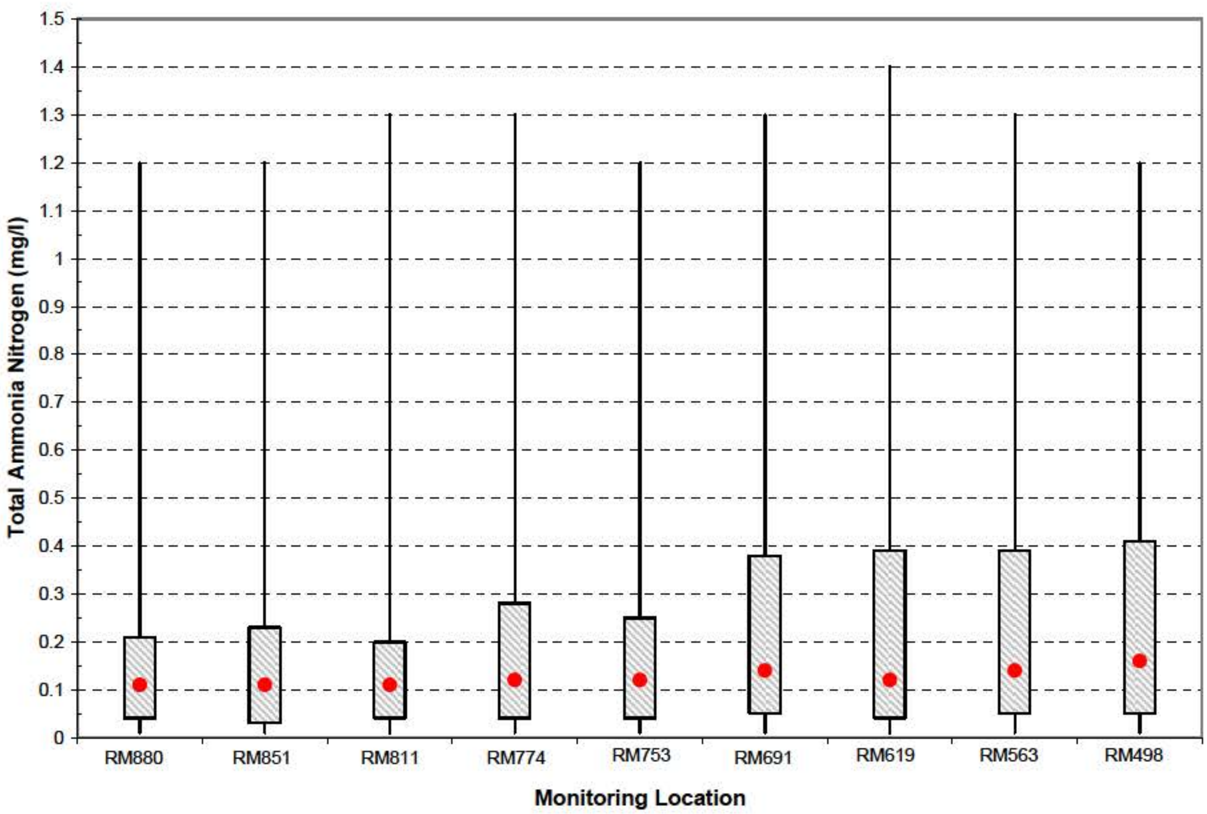
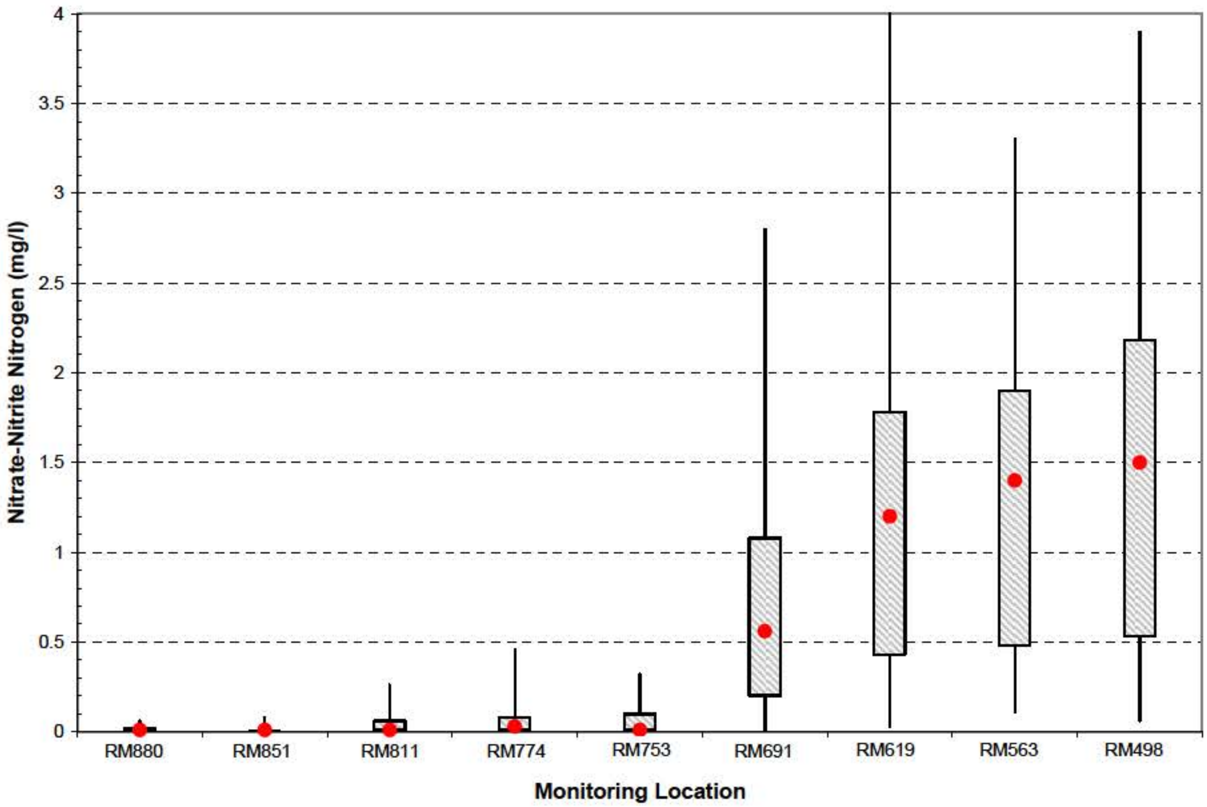


Plate I-103. (Continued).



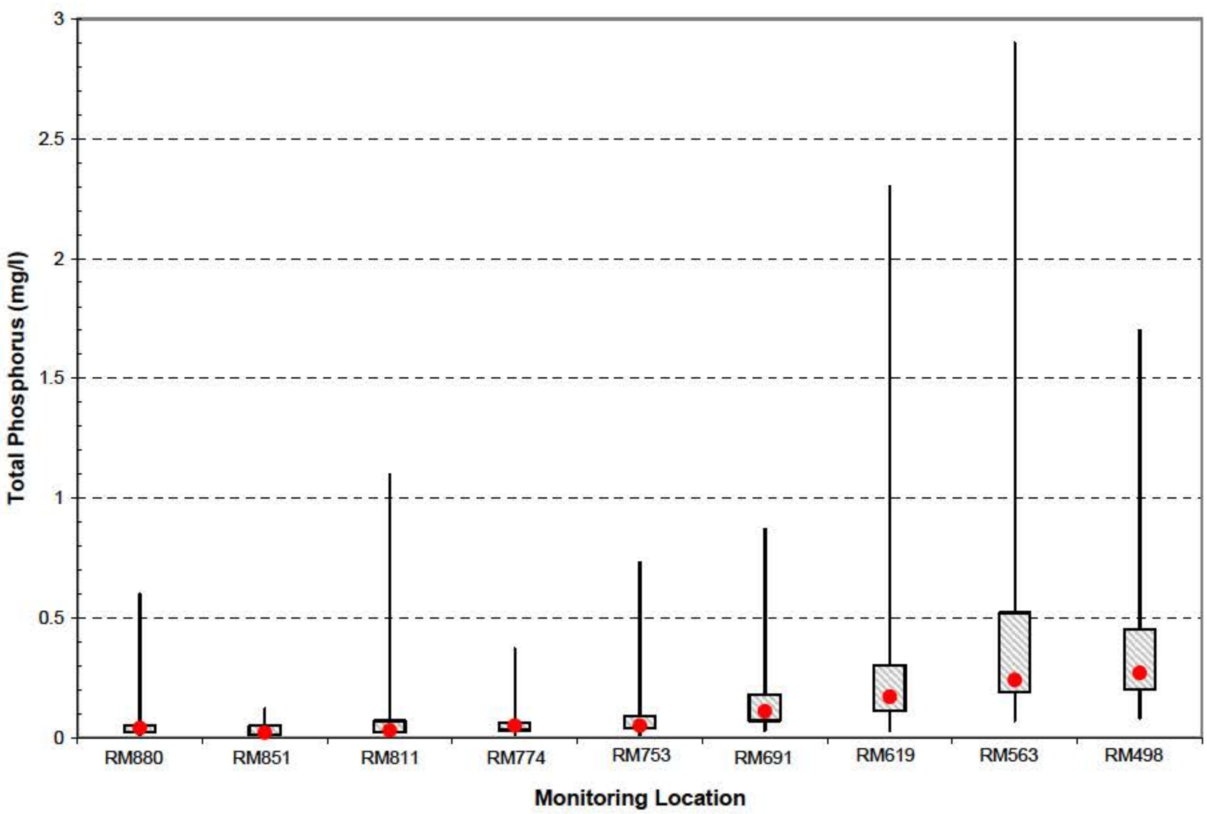


Plate I-103. (Continued).

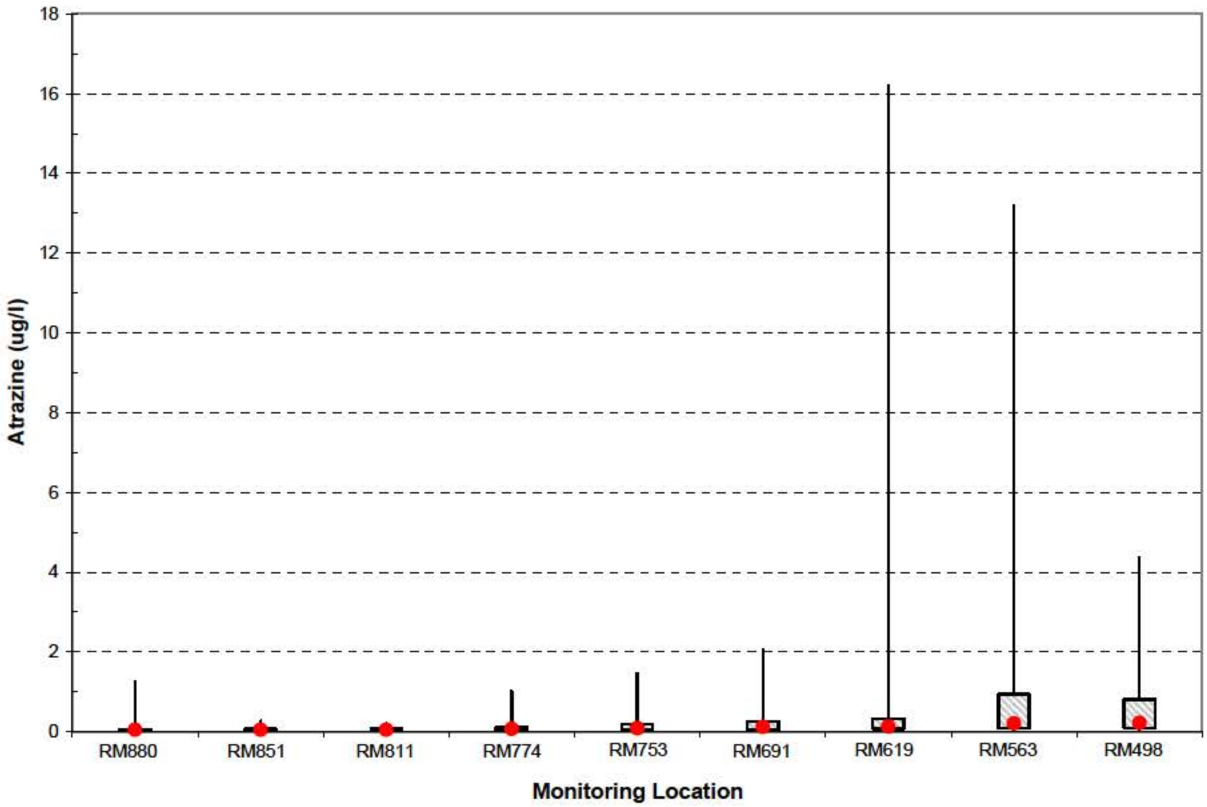


Plate 104. Summary of water quality conditions monitored in Ed Zorinsky Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	24	1110.1	1110.2	1108.7	1110.8	-----	-----	-----
Water Temperature (C)	0.1	280	22.1	22.7	12.4	28.2	32	0	0%
Dissolved Oxygen (mg/l)	0.1	271	6.2	6.6	0.0	11.0	≥ 5.0	61	23%
Dissolved Oxygen (% Sat.)	0.1	254	73.1	83.5	0.0	135.6	-----	-----	-----
Specific Conductance (umho/cm)	1	263	439	437	351	555	-----	-----	-----
pH (S.U.)	0.1	280	8.2	8.3	7.0	10.1	≥6.5 & ≤9.0	8	3%
Turbidity (NTUs)	0.1	94	13.4	14.1	0.6	32.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	143	314	308	66	434	-----	-----	-----
Secchi Depth (in.)	1	24	42	31	4	120	-----	-----	-----
Alkalinity, Total (mg/l)	7	41	143	140	110	195	-----	-----	-----
Ammonia, Total (mg/l)	0.01	28	0.37	0.26	n.d.	2.0	4.7 (1,2), 0.93 (1,3)	0, 2	0%, 7%
Chlorophyll *a* (ug/l) – Field Probe	1	66	5.9	5.2	n.d.	20	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	20	30	19	5	100	-----	-----	-----
Hardness, Total (mg/l)	0.4	14	151	151	118	179	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	41	0.8	0.7	n.d.	3.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	39	-----	n.d.	n.d.	0.77	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	41	0.10	0.06	0.01	0.49	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	38	-----	n.d.	n.d.	0.41	-----	-----	-----
Suspended Solids, Total (mg/l)	4	41	-----	8	n.d.	28	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88(2), 30(3)	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	4	n.d.	5	340(2), 16.7(3,4)	0	0%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	130(2), 5.3(3)	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	6	8.8(2), 0.3(3)	0, 1	0%, 25%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	830(2), 108(3)	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	19.8(2), 12.7(3)	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	101(2), 3.9(3)	0	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	0.051(3,4)	0	0
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	664(2), 74(3)	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20(2), 5(3)	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	7.0(2)	0	0%
Zinc, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	4	166(2,3)	0	0%
Alachlor, Total (ug/l)	0.05	14	-----	n.d.	n.d.	0.13	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)	0.05	17	1.45	1.19	0.05	3.03	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)	0.05	17	0.16	0.16	n.d.	0.35	390(2), 100(3)	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.****	n.d.	n.d.****	*****	0	0%
Microcystins, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1)Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 3 and 22.7 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 151 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Pesticides detected with median and maximum values given in parentheses: Isopropalin (n.d , 0.75), Acetochlor (n.d., 0.20), and Metribuzin (0.05, 0.14)

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 105. Summary of water quality conditions monitored in Glenn Cunningham Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	**No. of Obs.**	**Mean***	**Median**	**Min.**	**Max.**	**State WQS Criteria****	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	24	1121.3	1121.4	1120.5	1122.4	-----	-----	-----
Water Temperature (C)	0.1	260	22.2	23.5	11.2	27.6	32	0	0%
Dissolved Oxygen (mg/l)	0.1	252	5.6	6.1	0.0	10.4	≥ 5.0	79	31%
Dissolved Oxygen (% Sat.)	0.1	252	65.5	72.1	0.0	120.4	-----	-----	-----
Specific Conductance (umho/cm)	1	243	366	359	302	440	-----	-----	-----
pH (S.U.)	0.1	259	8.2	8.2	7.2	9.2	≥6.5 & ≤9.0	13	5%
Turbidity (NTUs)	0.1	117	23.4	17.5	12.3	74.6	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	151	380	381	250	467	-----	-----	-----
Secchi Depth (in.)	1	16	19	20	11	28	-----	-----	-----
Alkalinity, Total (mg/l)	7	41	176	180	101	206	-----	-----	-----
Ammonia, Total (mg/l)	0.01	28	0.25	0.21	n.d.	0.77	$5.7^{(1,2)}$, $1.06^{(1,3)}$	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	81	61	48	15	150	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	20	34	27	10	78	-----	-----	-----
Hardness, Total (mg/l)	0.4	12	188	193	155	217	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	41	1.2	1.2	0.5	1.9	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	41	-----	n.d.	n.d.	0.81	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	41	0.14	0 10	0.06	0.65	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	41	-----	n.d.	n.d.	0.06	-----	-----	-----
Suspended Solids, Total (mg/l)	4	41	17	14	n.d.	153	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	$88^{(2)}$, $30^{(3)}$	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	7	n.d.	8	$340^{(2)}$, $16.7^{(3,4)}$	0	0%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	$130^{(2)}$, $5.3^{(3)}$	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	$11.2^{(2)}$, $0.4^{(3)}$	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	$1{,}014^{(2)}$, $132^{(3)}$	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	$25.0^{(2)}$, $15.7^{(3)}$	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	$131^{(2)}$, $5.1^{(3)}$	0	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	$1.4^{(2)}$	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	$0.051^{(3,4)}$	0	0
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	$817^{(2)}$, $91^{(3)}$	0	0%
Selenium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	$20^{(2)}$, $5^{(3)}$	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	$10.7^{(2)}$	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	3	$205^{(2,3)}$	0	0%
Alachlor, Total (ug/l)	0.05	14	-----	n.d.	n.d.	0.10	$760^{(2)}$, $76^{(3)}$	0	0%
Atrazine, Total (ug/l)	0.05	16	1.53	1.56	0 55	2.29	$330^{(2)}$, $12^{(3)}$	0	0%
Metolachlor, Total (ug/l)	0.05	15	-----	0.06	n.d.	0.46	$390^{(2)}$, $100^{(3)}$	0	0%
Pesticide Scan (ug/l)***	0.05	5	-----	n.d.****	n.d.	n.d.****	*****	0	0%
Microcystins, Total (ug/l)	0.2	3	-----	0.2	n.d.	0.2	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** $^{(1)}$Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 2 and 23.5 respectively.
$^{(2)}$ Acute criterion for aquatic life.
$^{(3)}$ Chronic criterion for aquatic life.
$^{(4)}$ Human health criterion for surface waters.
$^{(5)}$ Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 193 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Pesticides detected with median and maximum values given in parentheses: Acetochlor (n.d., 0.30).

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 106. Summary of water quality conditions monitored in Standing Bear Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 4-year period 2002 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	20	1103.9	1104.0	1101.9	1104.9	-----	-----	-----
Water Temperature (C)	0.1	219	22.0	22.6	12.8	28.5	32	0	0%
Dissolved Oxygen (mg/l)	0.1	219	6.2	6.9	0.0	11.1	≥ 5.0	60	27%
Dissolved Oxygen (% Sat.)	0.1	219	72.9	82.8	0.0	143.5	-----	-----	-----
Specific Conductance (umho/cm)	1	219	323	321	241	449	-----	-----	-----
pH (S.U.)	0.1	219	8.2	8.3	7.0	9.8	≥6.5 & ≤9.0	6	3%
Turbidity (NTUs)	0.1	113	25.9	20.4	3.6	78.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	146	316	336	-3	454	-----	-----	-----
Secchi Depth (in.)	1	20	27	26	13	61	-----	-----	-----
Alkalinity, Total (mg/l)	7	37	114	110	80	160	-----	-----	-----
Ammonia, Total (mg/l)	0.01	25	0.35	0.29	n.d.	1.50	4.7 [1,2], 0.93 [1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	75	18	8	n.d.	100	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	16	28	20	7	71	-----	-----	-----
Hardness, Total (mg/l)	0.4	9	116	113	97	146	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	39	0.9	0.8	n.d.	2.8	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	39	-----	n.d.	n.d.	0.22	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	39	0.09	0.06	0.02	0 37	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	39	-----	n.d.	n.d.	0.12	-----	-----	-----
Suspended Solids, Total (mg/l)	4	38	14	13	n.d.	46	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	5	n.d.	6	340[2], 16.7[3,4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	6.6[2], 0.3[3]	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	654[2], 85[3]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	15.1[2], 9.9[3]	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	74[2], 2.9[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	0.051[3,4]	0	0
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	519[2], 58[3]	0	0%
Selenium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	4.3[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	3	130[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	16	-----	n.d.	n.d.	0.07	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	17	0.69	0.65	0 26	2.17	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)	0.05	16	-----	n.d.	n.d.	0.19	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	3	-----	n.d.	n.d.	n.d.	****	0	0%
Microcystins, Total (ug/l)	0.2	3	-----	n.d.	n.d.	0.13	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 3 and 22.6 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 113 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 107. Summary of water quality conditions monitored in Wehrspann Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 4-year period 2002 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

	Monitoring Results						Water Quality Standards Attainment		
Parameter	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	20	1092.4	1092.3	1089.5	1095.4	-----	-----	-----
Water Temperature (C)	0.1	204	22.1	22.5	13.3	29.1	32	0	0%
Dissolved Oxygen (mg/l)	0.1	204	7.0	7.6	0.0	11.1	≥ 5.0	36	18%
Dissolved Oxygen (% Sat.)	0.1	204	82.6	89.6	0.4	142.9	-----	-----	-----
Specific Conductance (umho/cm)	1	204	371	372	300	452	-----	-----	-----
pH (S.U.)	0.1	204	8.5	8.6	7.1	9.1	≥6.5 & ≤9.0	7	3%
Turbidity (NTUs)	0.1	95	18.6	15.9	3.8	72.3	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	107	358	363	167	441	-----	-----	-----
Secchi Depth (in.)	1	20	24	20	11	57	-----	-----	-----
Alkalinity, Total (mg/l)	7	39	128	129	99	192	-----	-----	-----
Ammonia, Total (mg/l)	0.01	25	0.24	0.14	n.d.	0.67	2.64 [(1,2)], 0.55 [(1,3)]	0, 4	0%, 16%
Chlorophyll *a* (ug/l) – Field Probe	1	67	23	18	n.d.	89	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	18	40	33	10	100	-----	-----	-----
Hardness, Total (mg/l)	0.4	10	127	118	104	180	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	39	1.0	1.1	0.2	1.5	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	39	-----	n.d.	n.d.	0.14	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	39	0.15	0 12	n.d.	1.00	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	39	-----	n.d.	n.d.	0.09	-----	-----	-----
Suspended Solids, Total (mg/l)	4	39	15	16	5	32	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88[(2)], 30[(3)]	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	10	n.d.	10	340[(2)], 16.7[(3,4)]	0	0%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	130[(2)], 5.3[(3)]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	6.9[(2)], 0.3[(3)]	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	678[(2)], 88[(3)]	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	15.7[(2)], 10 3[(3)]	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	44	77[(2)], 3.0[(3)]	0, 1	0%, 25%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	0.02	1.4[(2)]	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	0.051[(3,4)]	0	0
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	539[(2)], 60[(3)]	0	0%
Selenium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	20[(2)], 5[(3)]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	4.6[(2)]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	3	n.d.	5	135[(2,3)]	0	0%
Alachlor, Total (ug/l)	0.05	16	-----	0.03	n.d.	0.10	760[(2)], 76[(3)]	0	0%
Atrazine, Total (ug/l)	0.05	18	1.78	1.70	0 53	2.78	330[(2)], 12[(3)]	0	0%
Metolachlor, Total (ug/l)	0.05	15	0.20	0.14	n.d.	0.89	390[(2)], 100[(3)]	0	0%
Pesticide Scan (ug/l)***	0.05	3	-----	n.d.****	n.d.	n.d.****	*****	0	0%
Microcystins, Total (ug/l)	0.2	3	-----	n.d.	n.d.	0.13	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [(1)]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.6 and 22.5 respectively.
[(2)] Acute criterion for aquatic life.
[(3)] Chronic criterion for aquatic life.
[(4)] Human health criterion for surface waters.
[(5)] Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 118 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Pesticides detected with median and maximum values given in parentheses: Trifluralin (n.d., 0.21) and Metribuzin (0.10, 0.12).

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

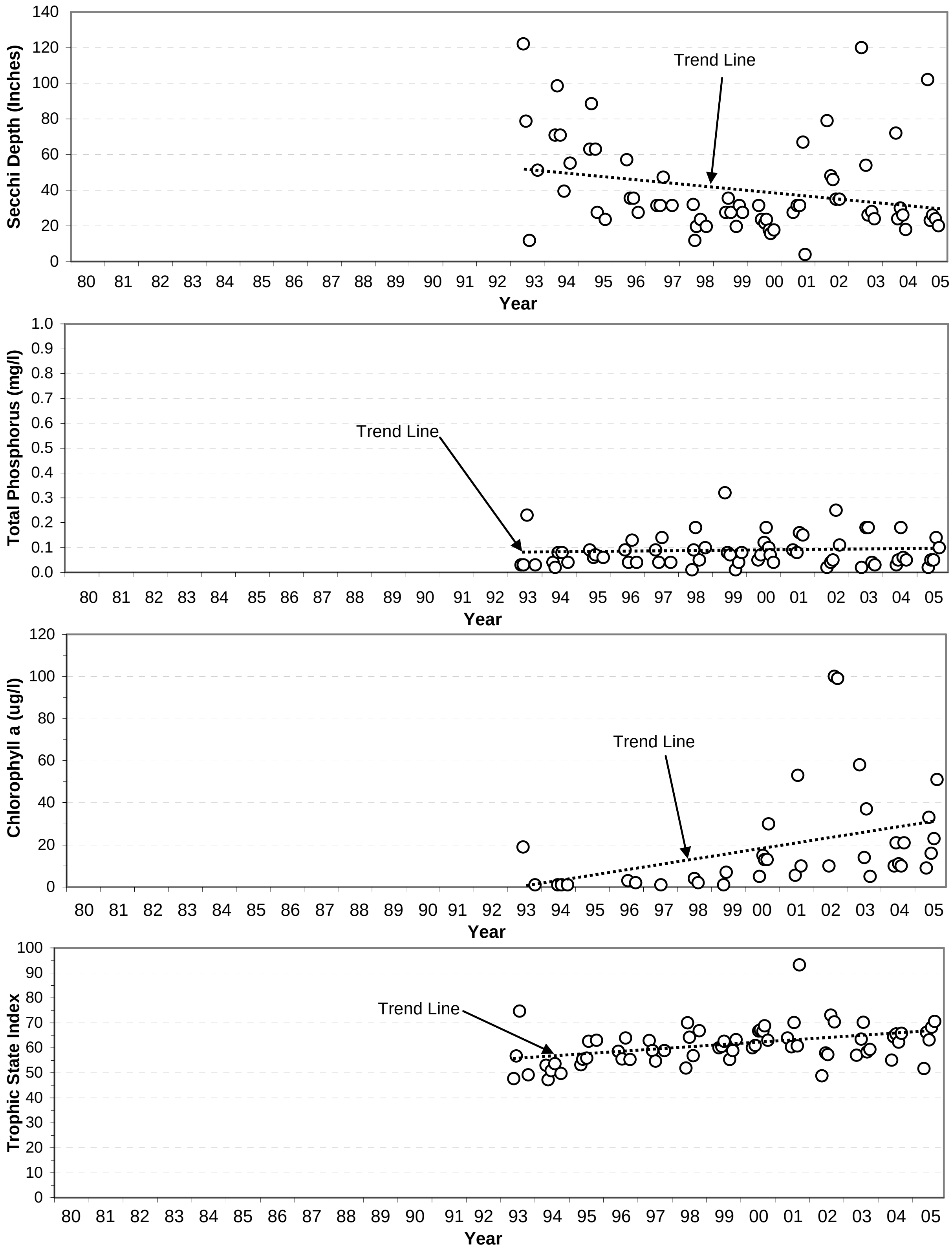


Plate 108. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Ed Zorinsky Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

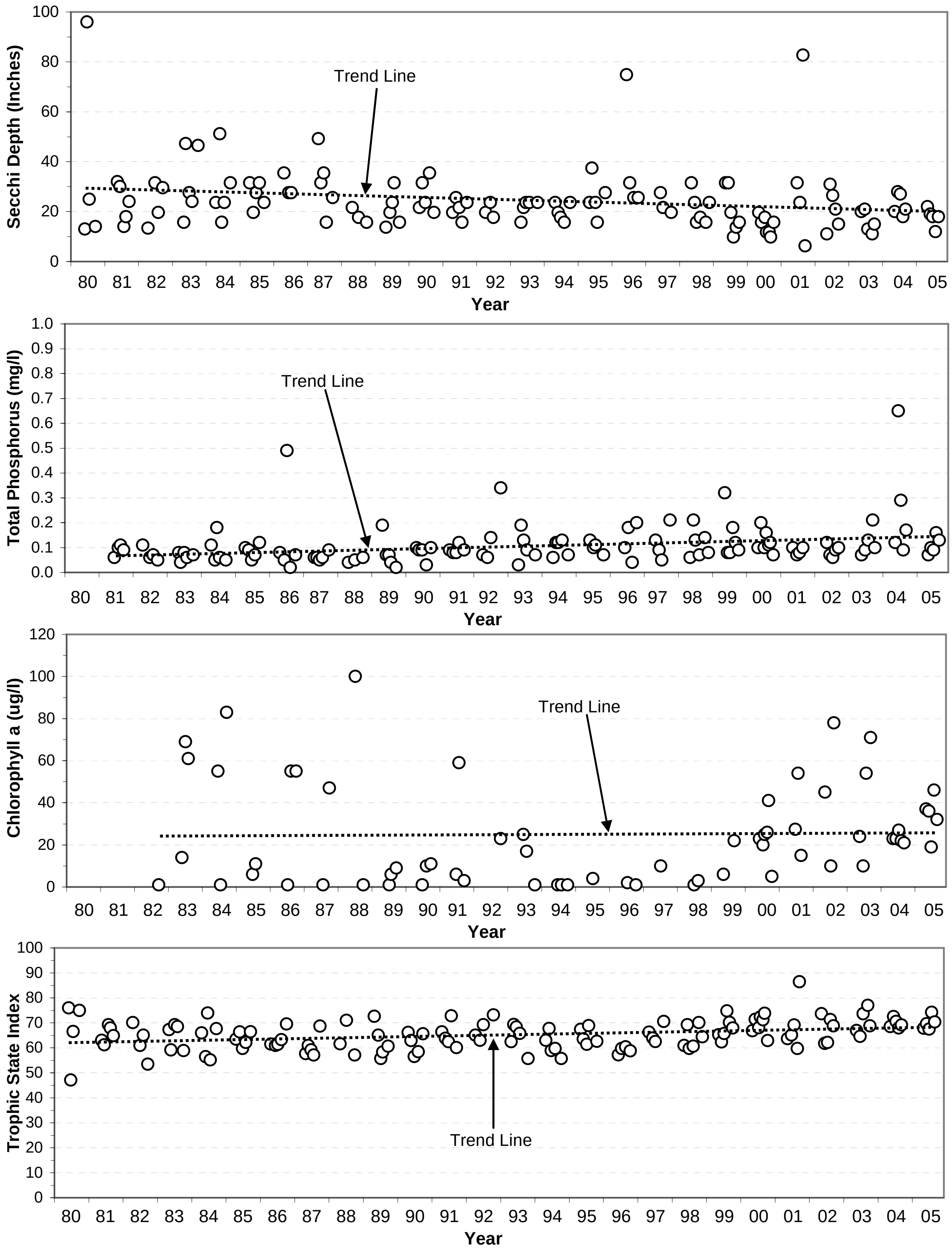


Plate 109. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Glenn Cunningham Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

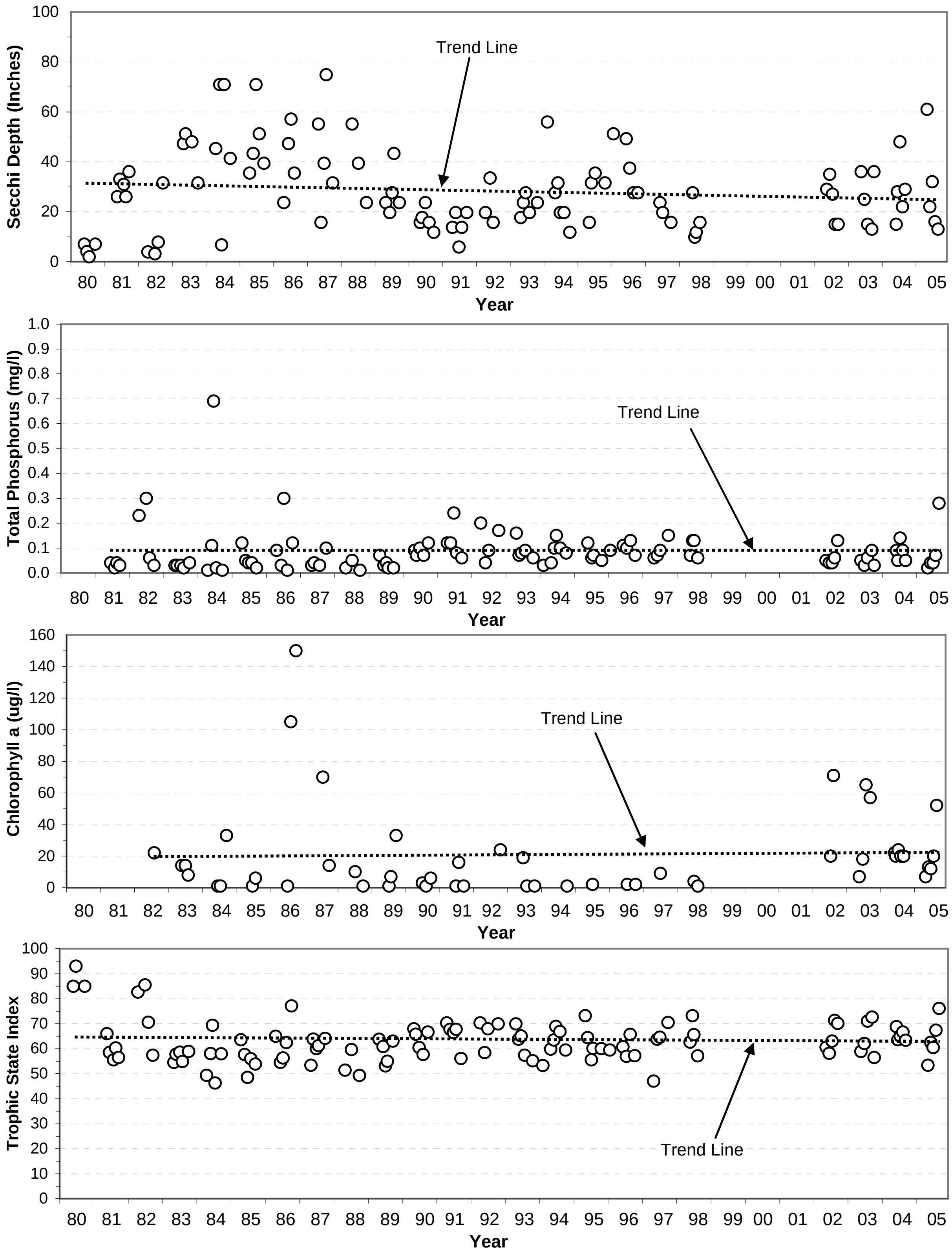


Plate 110. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Standing Bear Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

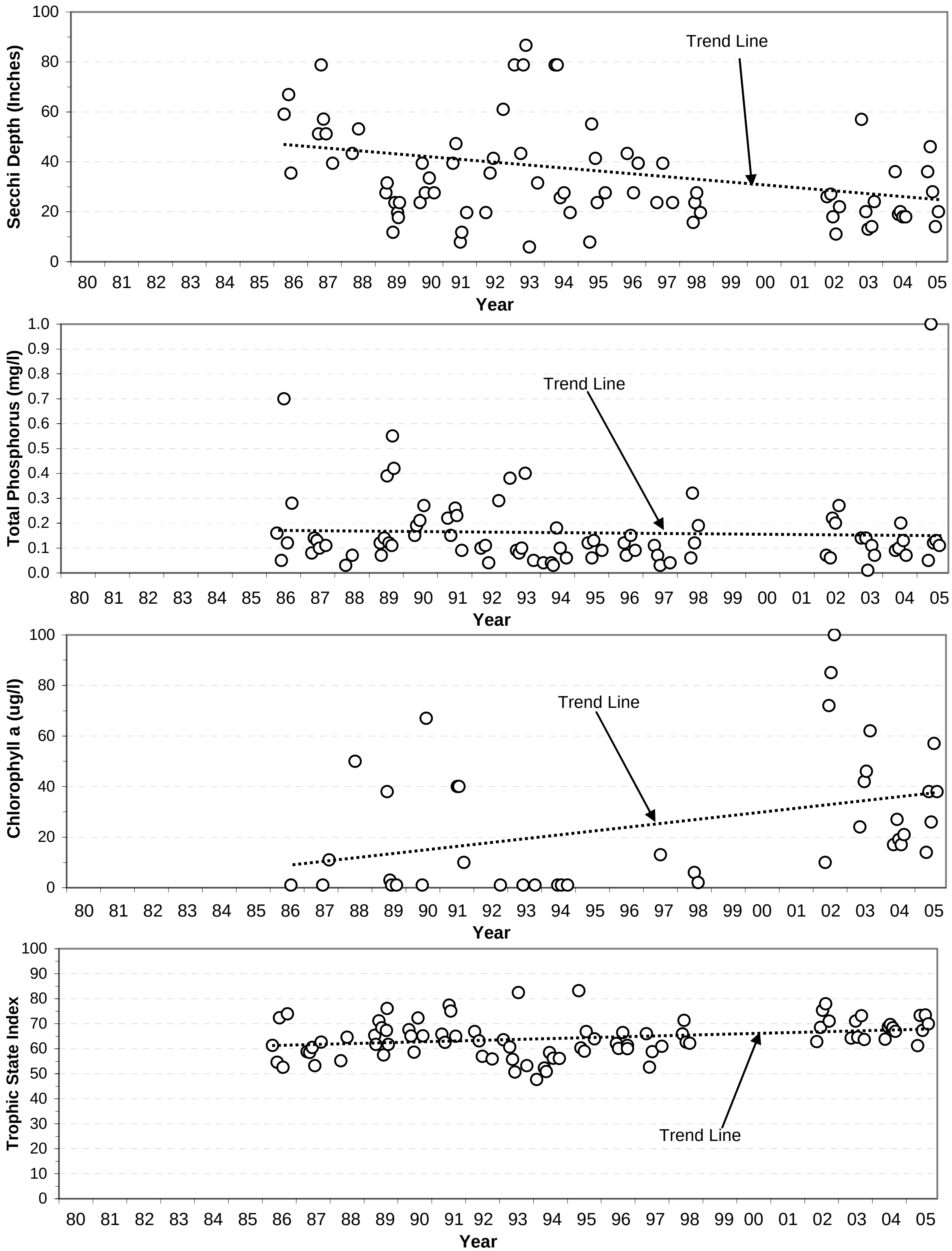


Plate 111. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Wehrspann Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

Plate 112. Summary of water quality conditions monitored in Bluestem Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 4-year period 2002 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	20	1306.4	1306.7	1303.8	1308.0	-----	-----	-----
Water Temperature (C)	0.1	155	21.9	22.5	15.1	28.1	32	0	0%
Dissolved Oxygen (mg/l)	0.1	155	6.8	7.1	0.4	8.8	≥ 5.0	10	6%
Dissolved Oxygen (% Sat.)	0.1	155	80.5	83.1	5.0	113.7	-----	-----	-----
Specific Conductance (umho/cm)	1	154	279	292	187	339	-----	-----	-----
pH (S.U.)	0.1	155	8.0	8.0	7.1	8.9	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	87	157	117	49	502	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	103	402	399	351	488	-----	-----	-----
Secchi Depth (in.)	1	20	8	6	2	24	-----	-----	-----
Alkalinity, Total (mg/l)	7	39	107	114	46	149	-----	-----	-----
Ammonia, Total (mg/l)	0.01	25	0.29	0.23	n.d.	1.00	8.40[1,2], 1.45 [1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	43	29	34	14	59	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	16	22	3	n.d.	101	-----	-----	-----
Hardness, Total (mg/l)	0.4	13	141	146	99	159	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	40	0.8	0.9	n.d.	3.0	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	38	0.72	0.68	n.d.	1.70	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	40	0.24	0 21	0.02	0 99	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	40	0.09	0.08	0.03	0 17	-----	-----	-----
Suspended Solids, Total (mg/l)	4	40	43	31	13	140	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	3	340[2], 16.7[3,4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	6	8.5[2], 0.3[3]	0, 1	0%,33%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	807[2], 105[3]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	2	19.2[2], 12.4[3]	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	44	97[2], 3.8[3]	0, 1	0%, 25%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	0.02	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	0.02	0.051[3,4]	0	0
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	645[2], 72[3]	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	4.6[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	3	n.d.	5	161[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	19	0.36	0.31	0.08	0.98	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	21	1.97	1.39	n.d.	11.60	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)	0.05	20	1.39	1.11	0 29	2.90	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.****	n.d.	n.d.****	*****	0	0%
Microcystins, Total (ug/l)	0.2	4	-----	n.d.	n.d.	0.53	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.0 and 22.5 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 146 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Pesticides detected with median and maximum values given in parentheses: Trifluralin (n.d., 0.21) and Metribuzin (0.10, 0.12).

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 113. Summary of water quality conditions monitored in Branched Oak Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	26	1280.4	1279.5	1278.5	1284.5	-----	-----	-----
Water Temperature (C)	0.1	319	21.2	22.0	6.7	29.1	32	0	0%
Dissolved Oxygen (mg/l)	0.1	319	7.1	6.9	0.2	13.0	≥ 5.0	22	7%
Dissolved Oxygen (% Sat.)	0.1	319	81.8	81.7	2.3	173.2	-----	-----	-----
Specific Conductance (umho/cm)	1	298	390	391	354	424	-----	-----	-----
pH (S.U.)	0.1	319	8.3	8.3	7.1	9.1	≥6.5 & ≤9.0	2	1%
Turbidity (NTUs)	0.1	122	24.6	23.5	16.1	59.3	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	149	4.1	4.4	314	515	-----	-----	-----
Secchi Depth (in.)	1	26	18	18	6	28	-----	-----	-----
Alkalinity, Total (mg/l)	7	46	166	168	124	190	-----	-----	-----
Ammonia, Total (mg/l)	0.01	31	0.25	0.17	n.d.	1.30	4.71[1,2], 0.94 [1,3]	0, 1	0%, 3%
Chlorophyll *a* (ug/l) – Field Probe	1	71	38	33	12	86	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	21	27	20	6	108	-----	-----	-----
Hardness, Total (mg/l)	0.4	24	163	167	97	187	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	46	0.9	1.0	0.2	1.5	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	44	-----	n.d.	n.d.	0.33	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	46	0.12	0.09	n.d.	0.76	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	46	-----	n.d.	n.d.	0.02	-----	-----	-----
Suspended Solids, Total (mg/l)	4	46	17	17	n.d.	32	-----	-----	-----
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	4	n.d.	4	340[2], 16.7[3,4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	9.7[2], 0.4[3]	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	901[2], 117[3]	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	21.8[2], 13 9[3]	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	112[2], 4.4[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	8	723[2], 80[3]	0	0%
Selenium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	8.3[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	6	n.d.	23	181[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	18	0.19	0.18	n.d.	0.34	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	18	2.29	2.23	0 94	3.16	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)	0.05	17	0.13	0.11	n.d.	0.37	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	5	-----	n.d.	n.d.	n.d.	****	0	0%
Microcystins, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 3 and 22.0 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 167 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 114. Summary of water quality conditions monitored in Conestoga Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 4-year period 2002 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	20	1230.9	1230.8	1228.9	1232.8	-----	-----	-----
Water Temperature (C)	0.1	149	22.5	22.8	15.8	28.9	32	0	0%
Dissolved Oxygen (mg/l)	0.1	149	7.4	7.4	0.5	15.9	≥ 5.0	14	9%
Dissolved Oxygen (% Sat.)	0.1	149	87.8	86.7	6.8	196.6	-----	-----	-----
Specific Conductance (umho/cm)	1	149	398	396	316	476	-----	-----	-----
pH (S.U.)	0.1	149	8.5	8.5	7.7	9.2	≥6.5 & ≤9.0	17	11%
Turbidity (NTUs)	0.1	73	38.8	34.5	6.9	91.0	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	90	397	384	333	509	-----	-----	-----
Secchi Depth (in.)	1	20	21	16	6	55	-----	-----	-----
Alkalinity, Total (mg/l)	7	40	147	147	110	188	-----	-----	-----
Ammonia, Total (mg/l)	0.01	25	0.39	0.24	n.d.	1.30	3.20[1,2], 0.64 [1,3]	0, 7	0%, 28%
Chlorophyll *a* (ug/l) – Field Probe	1	41	19	17	6	84	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	19	56	20	8	476	-----	-----	-----
Hardness, Total (mg/l)	0.4	16	165	163	136	200	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	40	1.5	1.5	n.d.	3.6	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	36	-----	n.d.	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	40	0.18	0 16	0.05	0 52	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	40	-----	0.03	n.d.	0.37	-----	-----	-----
Suspended Solids, Total (mg/l)	4	40	20	19	6	49	-----	-----	-----
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	6	n.d.	9	340[2], 16.7[3,4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	9.5[2], 0.4[3]	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	883[2], 115[3]	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	21.3[2], 13.6[3]	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	109[2], 4.3[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	0.02	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	0.02	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	n.d.	708[2], 79[3]	0	0%
Selenium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	8.0[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	7	177[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	22	0.43	0.37	0.07	0.93	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	22	3.42	3.37	1.83	5.90	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)	0.05	22	0.27	0.21	0.09	0.87	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.****	n.d.	n.d.****	*****	0	0%
Microcystins, Total (ug/l)	0.2	3	-----	n.d.	n.d.	3.3	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 5 and 22.8 respectively.

[2] Acute criterion for aquatic life.

[3] Chronic criterion for aquatic life.

[4] Human health criterion for surface waters.

[5] Daily maximum criterion for domestic water supply.

Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 163 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Pesticides detected with median and maximum values given in parentheses: Acetochlor (n.d., 0.10) and Metribuzin (n.d., 0.10).

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 115. Summary of water quality conditions monitored in East Twin Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 4-year period 2002 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	20	1339.9	1339.9	1337.9	1341.5	-----	-----	-----
Water Temperature (C)	0.1	216	22.1	22.7	14.6	28.7	32	0	0%
Dissolved Oxygen (mg/l)	0.1	216	6.8	7.1	0.1	11.6	≥ 5.0	28	13%
Dissolved Oxygen (% Sat.)	0.1	216	80.3	73.3	1.5	143.0	-----	-----	-----
Specific Conductance (umho/cm)	1	216	361	367	311	573	-----	-----	-----
pH (S.U.)	0.1	216	8.2	8.2	7.1	8.8	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	100	32.0	27.8	9.2	237.0	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	118	366	364	84	482	-----	-----	-----
Secchi Depth (in.)	1	20	23	26	2	36	-----	-----	-----
Alkalinity, Total (mg/l)	7	40	138	142	81	176	-----	-----	-----
Ammonia, Total (mg/l)	0.01	25	0.33	0.19	0.02	1.10	5.72(1,2), 1.06 (1,3)	0, 2	0%, 8%
Chlorophyll *a* (ug/l) – Field Probe	1	61	17	16	5	32	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	17	30	20	3	83	-----	-----	-----
Hardness, Total (mg/l)	0.4	8	156	156	132	180	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	40	1.5	1.1	0.4	16.0	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	40	-----	n.d.	n.d.	0.52	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	40	0.15	0.09	0.02	2 50	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	40	-----	n.d.	n.d.	0.03	-----	-----	-----
Suspended Solids, Total (mg/l)	4	40	16	14	4	75	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88(2), 30(3)	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	3	340(2), 16.7(3,4)	0	0%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	130(2), 5.3(3)	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	0.23	9.1(2), 0.3(3)	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	852(2), 111(3)	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20.4(2), 13 1(3)	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	104(2), 4.1(3)	0	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	0.02	0.051(3,4)	0	0%
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	n.d.	682(2), 76(3)	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20(2), 5(3)	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	7.4(2)	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	4	n.d.	8	171(2,3)	0	0%
Alachlor, Total (ug/l)	0.05	18	1.18	1.06	0.40	1.85	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)	0.05	18	2.68	2.58	1 58	5.23	330(2), 12(3)	0	0%
Metolachlor, Total (ug/l)	0.05	18	0.84	0.51	0.08	2.80	390(2), 100(3)	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.****	n.d.	n.d.****	*****	0	0%
Microcystins, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1)Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 5 and 22.8 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 156 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Pesticides detected with median and maximum values given in parentheses: Acetochlor (n.d., 0.20) and Prometon (n.d , 0.10).

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 116. Summary of water quality conditions monitored in Olive Creek Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 3-year period of 2003 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	15	1331.3	1331.0	1328.7	1334.2	-----	-----	-----
Water Temperature (C)	0.1	76	22.0	22.5	15.9	26.2	32	0	0%
Dissolved Oxygen (mg/l)	0.1	76	6.8	7.1	0.9	11.1	≥ 5.0	11	14%
Dissolved Oxygen (% Sat.)	0.1	76	80.0	81.6	10.7	123.3	-----	-----	-----
Specific Conductance (umho/cm)	1	76	228	210	171	315	-----	-----	-----
pH (S.U.)	0.1	76	8.6	8.4	7.4	10.2	≥6.5 & ≤9.0	31	41%
Turbidity (NTUs)	0.1	49	68.1	73.0	23.4	123.9	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	62	386	376	176	461	-----	-----	-----
Secchi Depth (in.)	1	15	12	10	2	25	-----	-----	-----
Alkalinity, Total (mg/l)	7	30	124	120	87	203	-----	-----	-----
Ammonia, Total (mg/l)	0.01	25	0.36	0.25	n.d.	1.20	5.72[1,2], 1.06 [1,3]	0, 2	0%, 8%
Chlorophyll *a* (ug/l) – Field Probe	1	30	19	18	9	34	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	14	39	27	1	170	-----	-----	-----
Hardness, Total (mg/l)	0.4	7	113	114	79	155	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	30	2.6	2.4	0.5	6.3	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	30	-----	n.d.	n.d.	1.50	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	30	0.31	0 32	0.02	0.70	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	30	0.12	0 11	n.d.	0 26	-----	-----	-----
Suspended Solids, Total (mg/l)	4	30	30	28	11	56	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	3	24	22	16	35	340[2], 16.7[3,4]	0, 2	0%, 67%
Cadmium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	6.7[2], 0.3[3]	0	0%
Chromium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	659[2], 86[3]	0	0%
Copper, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	2	15.2[2], 10.0[3]	0	0%
Lead, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	74[2], 2.9[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	2	-----	n.d.	n.d.	0.02	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	0.02	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	n.d.	523[2], 58[3]	0	0%
Selenium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	4.3[2]	0	0%
Zinc, Dissolved (ug/l)	3	2	-----	4	n.d.	8	131[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	14	0.25	0.24	0.06	0.54	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	15	3.94	2.50	n.d.	13.30	330[2], 12[3]	0, 1	0%, 7%
Metolachlor, Total (ug/l)	0.05	14	0.73	0.41	0.09	2.12	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	3	-----	n.d.****	n.d.	n.d.****	*****	0	0%
Microcystins, Total (ug/l)	0.2	4	-----	0.4	n.d.	2.7	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.4 and 22.5 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 114 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Pesticides detected with median and maximum values given in parentheses: Acetochlor (n.d., 0.20), Metribuzin (n.d., 0.70) and Propazine (n.d., 0.10).

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 117. Summary of water quality conditions monitored in Pawnee Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1243.7	1243.6	1242.7	1244.5	-----	-----	-----
Water Temperature (C)	0.1	276	21.8	22.4	15.0	28.4	32	0	0%
Dissolved Oxygen (mg/l)	0.1	276	6.9	7.1	0.2	10.7	≥ 5.0	52	19%
Dissolved Oxygen (% Sat.)	0.1	276	80.3	84.5	2.0	140.6	-----	-----	-----
Specific Conductance (umho/cm)	1	260	359	368	303	399	-----	-----	-----
pH (S.U.)	0.1	276	8.4	8.3	6.9	9.0	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs)	0.1	119	14.8	5.3	2.1	247.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	143	387	379	326	490	-----	-----	-----
Secchi Depth (in.)	1	25	39	32	9	96	-----	-----	-----
Alkalinity, Total (mg/l)	7	43	171	174	103	200	-----	-----	-----
Ammonia, Total (mg/l)	0.01	30	0.44	0.35	n.d.	1.30	4.71[1,2], 0.92 [1,3]	0, 3	0%, 10%
Chlorophyll *a* (ug/l) – Field Probe	1	71	-----	1	n.d.	37	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	22	31	26	3	100	-----	-----	-----
Hardness, Total (mg/l)	0.4	21	151	146	123	195	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	45	1.2	1.2	0.2	2.4	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	43	-----	n.d.	n.d.	0.28	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	45	0.15	0 11	0.02	0.42	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	45	-----	0.01	n.d.	1.40	-----	-----	-----
Suspended Solids, Total (mg/l)	4	45	12	11	n.d.	58	-----	-----	-----
Antimony, Dissolved (ug/l)	6	3	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	4	-----	12	n.d.	25	340[2], 16.7[3,4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	8.5[2], 0.3[3]	0	0%
Chromium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	807[2], 105[3]	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	19.2[2], 12.4[3]	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	97[2], 3.8[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	4	-----	n.d.	n.d.	8	645[2], 72[3]	0	0%
Selenium, Total (ug/l)	2	4	-----	n.d.	n.d.	5	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	4.6[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	4	161[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	18	0.31	0.26	0.07	1.38	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	18	2.46	2.13	1.49	5.36	330[2], 12[3]	0	0%
Metolachlor, Total (ug/l)	0.05	18	0.17	0.15	n.d.	0.51	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	5	-----	n.d.	n.d.	n.d.	****	0	0%
Microcystins, Total (ug/l)	0.2	3	0.6	0.4	0.2	1.3	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 3 and 22.4 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 146 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 118. Summary of water quality conditions monitored in Stagecoach Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 5-year period 2001 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1271.1	1271.0	1270.0	1273.3	-----	-----	-----
Water Temperature (C)	0.1	179	22.6	23.1	15.6	30.0	32	0	0%
Dissolved Oxygen (mg/l)	0.1	179	6.5	6.7	0.2	13.0	≥ 5.0	38	21%
Dissolved Oxygen (% Sat.)	0.1	179	78.3	80.1	2.5	177.3	-----	-----	-----
Specific Conductance (umho/cm)	1	169	354	360	214	488	-----	-----	-----
pH (S.U.)	0.1	174	8.1	8.1	7.1	9.2	≥6.5 & ≤9.0	6	3%
Turbidity (NTUs)	0.1	71	73.9	33.5	8.4	529.3	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	95	381	377	286	483	-----	-----	-----
Secchi Depth (in.)	1	24	45	13	2	38	-----	-----	-----
Alkalinity, Total (mg/l)	7	44	152	159	50	210	-----	-----	-----
Ammonia, Total (mg/l)	0.01	30	0.30	0.22	n.d.	0.92	6.95[1,2], 1.21 [1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	46	61	50	31	122	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	22	35	22	n.d.	131	-----	-----	-----
Hardness, Total (mg/l)	0.4	20	167	159	132	214	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	45	1.1	1.1	n.d.	2.3	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	43	-----	n.d.	n.d.	2.0	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	45	0.30	0 24	0.07	0.71	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	45	0.13	0.08	n.d.	0.63	-----	-----	-----
Suspended Solids, Total (mg/l)	4	45	40	21	n.d.	370	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	3	-----	7	n.d.	11	340[2], 16.7[3,4]	0	0%
Beryllium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	9.3[2], 0.3[3]	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	866[2], 113[3]	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	20.8[2], 13 3[3]	0	0%
Lead, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	5	107[2], 4.2[3]	0, 1	0%, 25%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	0.02	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	3	-----	0.02	n.d.	0.03	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	8	693[2], 77[3]	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	5	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	7.7[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	5	174[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	18	0.22	0.24	0.07	0.38	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	19	3.25	2.24	n.d.	12.50	330[2], 12[3]	0, 1	0%, 5%
Metolachlor, Total (ug/l)	0.05	18	0.94	0.85	0 22	2.46	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	4	-----	n.d.****	n.d.	n.d.****	*****	0	0%
Microcystins, Total (ug/l)	0.2	3	----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1] Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 1 and 23.1 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 159 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Pesticides detected with median and maximum values given in parentheses: Acetochlor (n.d., 0.60).

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 119. Summary of water quality conditions monitored in Wagon Train Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 3-year period 2003 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	15	1286.1	1286.1	1284.5	1287.8	-----	-----	-----
Water Temperature (C)	0.1	127	21.9	22.6	14.9	30.8	32	0	0%
Dissolved Oxygen (mg/l)	0.1	127	6.2	6.4	0.0	12.6	≥ 5.0	30	24%
Dissolved Oxygen (% Sat.)	0.1	127	73.0	74.3	0.0	144.4	-----	-----	-----
Specific Conductance (umho/cm)	1	127	314	312	261	392	-----	-----	-----
pH (S.U.)	0.1	127	8.3	8.2	7.3	9.4	≥6.5 & ≤9.0	5	4%
Turbidity (NTUs)	0.1	85	31.4	26.2	1.8	117.6	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	101	381	384	69	480	-----	-----	-----
Secchi Depth (in.)	1	15	23	16	9	60	-----	-----	-----
Alkalinity, Total (mg/l)	7	29	149	150	90	190	-----	-----	-----
Ammonia, Total (mg/l)	0.01	25	0.34	0.25	n.d.	1.40	5.73(1,2), 1.06 (1,3)	0, 2	0%, 8%
Chlorophyll *a* (ug/l) – Field Probe	1	52	34	38	4	61	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	13	25	16	1	100	-----	-----	-----
Hardness, Total (mg/l)	0.4	9	130	133	114	143	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	30	1.3	1.3	n.d.	2.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	30	-----	n.d.	n.d.	1.10	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	30	0.33	0 32	0.09	0 55	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	30	0.21	0 22	0.06	0.41	-----	-----	-----
Suspended Solids, Total (mg/l)	4	30	13	14	n.d.	27	-----	-----	-----
Arsenic, Dissolved (ug/l)	3	3	19	19	16	21	340(2), 16.7(3,4)	2	67%
Cadmium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	7.8(2), 0.3(3)	0	0%
Chromium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	748(2), 97(3)	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	17.6(2), 11.4(3)	0	0%
Lead, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	5	88(2), 3.4(3)	0, 1	0%, 50%
Mercury, Dissolved (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	2	-----	0.02	n.d.	0.02	0.051(3,4)	0	0%
Nickel, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	n.d.	596(2), 66(3)	0	0%
Selenium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	20(2), 5(3)	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	5.6(2)	0	0%
Zinc, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	n.d.	149(2,3)	0	0%
Alachlor, Total (ug/l)	0.05	14	0.19	0.20	n.d.	0.35	760(2), 76(3)	0	0%
Atrazine, Total (ug/l)	0.05	15	3.89	3.40	n.d.	9.15	330(2), 12(3)	0, 1	0%, 5%
Metolachlor, Total (ug/l)	0.05	14	0.74	0.61	0 17	2.02	390(2), 100(3)	0	0%
Pesticide Scan (ug/l)***	0.05	2	-----	n.d.****	n.d.	n.d.****	*****	0	0%
Microcystins, Total (ug/l)	0.2	4	----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1)Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 2 and 22.6 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 133 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Pesticides detected with median and maximum values given in parentheses: Acetochlor (0.20, 0 30), Propazine (n.d., 0.20), and Metribuzin (n.d., 0.20).

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 120. Summary of water quality conditions monitored in West Twin Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 4-year period 2002 through 2005. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	18	1340.0	1340.0	1337.9	1341.5	-----	-----	-----
Water Temperature (C)	0.1	44	23.1	24.4	15.6	31.8	32	0	0%
Dissolved Oxygen (mg/l)	0.1	44	6.7	6.4	2.9	15.3	≥ 5.0	6	14%
Dissolved Oxygen (% Sat.)	0.1	44	81.5	74.6	36.2	208.1	-----	-----	-----
Specific Conductance (umho/cm)	1	44	505	484	417	651	-----	-----	-----
pH (S.U.)	0.1	44	8.3	8.3	7.7	10.2	≥6.5 & ≤9.0	1	2%
Turbidity (NTUs)	0.1	17	183.8	119.4	48	617.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	19	357	363	171	489	-----	-----	-----
Secchi Depth (in.)	1	15	7	6	3	10	-----	-----	-----
Alkalinity, Total (mg/l)	7	28	131	136	46	180	-----	-----	-----
Ammonia, Total (mg/l)	0.01	15	0.47	0.43	n.d.	1.30	4.71[1,2], 0.81 [1,3]	0, 2	0%, 13%
Chlorophyll *a* (ug/l) – Field Probe	1	7	139	142	113	150	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	17	42	30	6	139	-----	-----	-----
Hardness, Total (mg/l)	0.4	6	213	190	176	287	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	28	2.5	2.0	n.d.	9.6	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	26	-----	n.d.	n.d.	0.86	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	28	0.34	0 29	0.08	1 30	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	28	-----	0.01	n.d.	0.12	-----	-----	-----
Suspended Solids, Total (mg/l)	4	28	109	74	16	456	-----	-----	-----
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	88[2], 30[3]	0	0%
Arsenic, Dissolved (ug/l)	3	3	12	9	5	23	340[2], 16.7[3,4]	0, 1	0%, 33%
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	130[2], 5.3[3]	0	0%
Cadmium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	0.23	11.0[2], 0.4[3]	0	0%
Chromium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,002[2], 130[3]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	2	n.d.	4	24.6[2], 15 5[3]	0	0%
Lead, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	129[2], 5.0[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	0.02	0.051[3,4]	0	0%
Nickel, Dissolved (ug/l)	3	3	-----	n.d.	n.d.	4	806[2], 90[3]	0	0%
Selenium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	20[2], 5[3]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	10.4[2]	0	0%
Zinc, Dissolved (ug/l)	3	3	-----	4	n.d.	8	202[2,3]	0	0%
Alachlor, Total (ug/l)	0.05	17	2.20	2.02	0.61	4.81	760[2], 76[3]	0	0%
Atrazine, Total (ug/l)	0.05	17	4.91	2.61	0 54	32.80	330[2], 12[3]	0, 2	0%, 12%
Metolachlor, Total (ug/l)	0.05	17	1.27	0.81	0 13	4.88	390[2], 100[3]	0	0%
Pesticide Scan (ug/l)***	0.05	3	-----	n.d.****	n.d.	n.d.****	*****	0	0%
Microcystins, Total (ug/l)	0.2	2	-----	0.9	n.d.	1.9	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** [1]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8 3 and 24.4 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 190 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Pesticides detected with median and maximum values given in parentheses: Acetochlor (0.70, 1.50) and Metribuzin (n.d , 0.10).

***** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

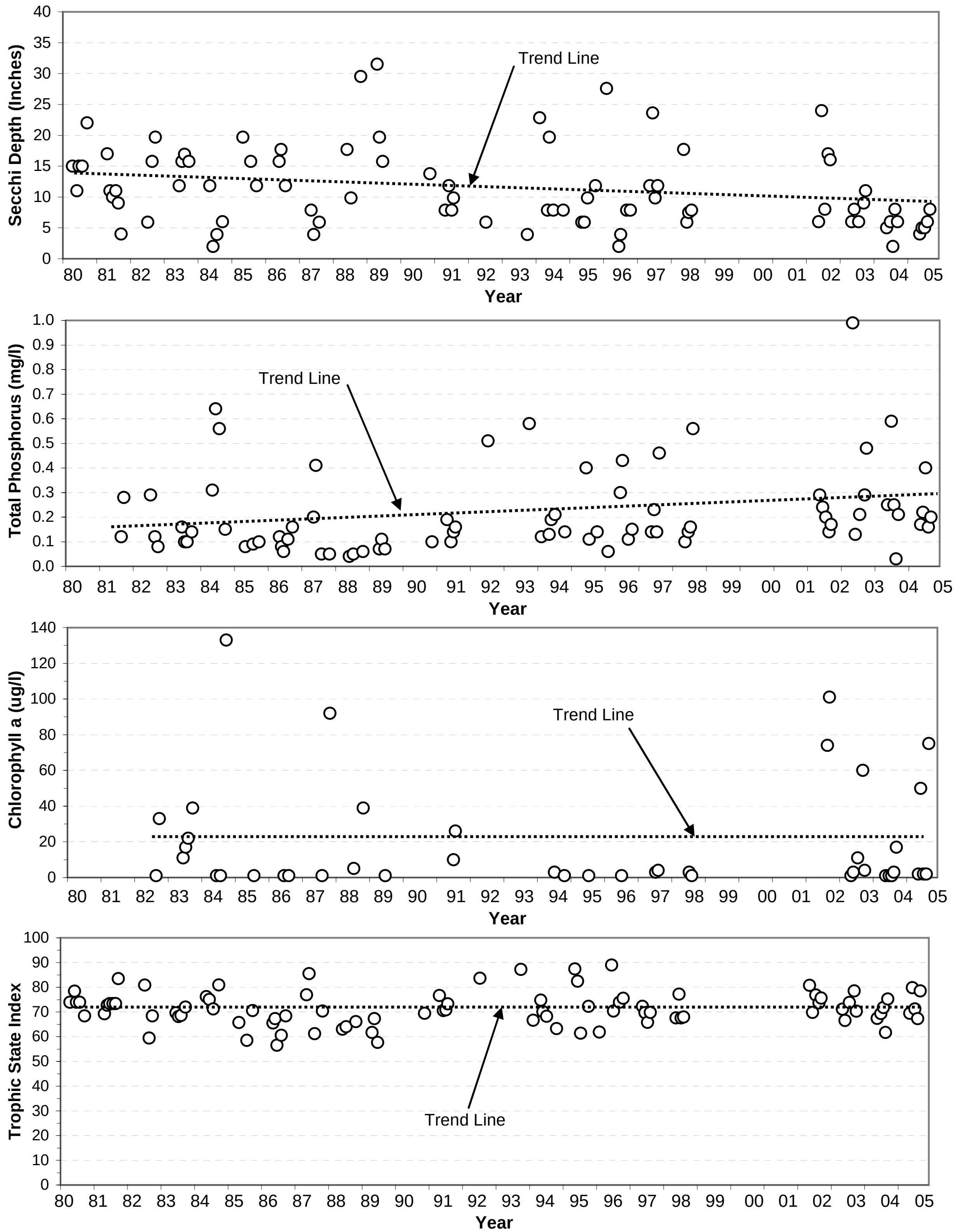


Plate 121. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Bluestem Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

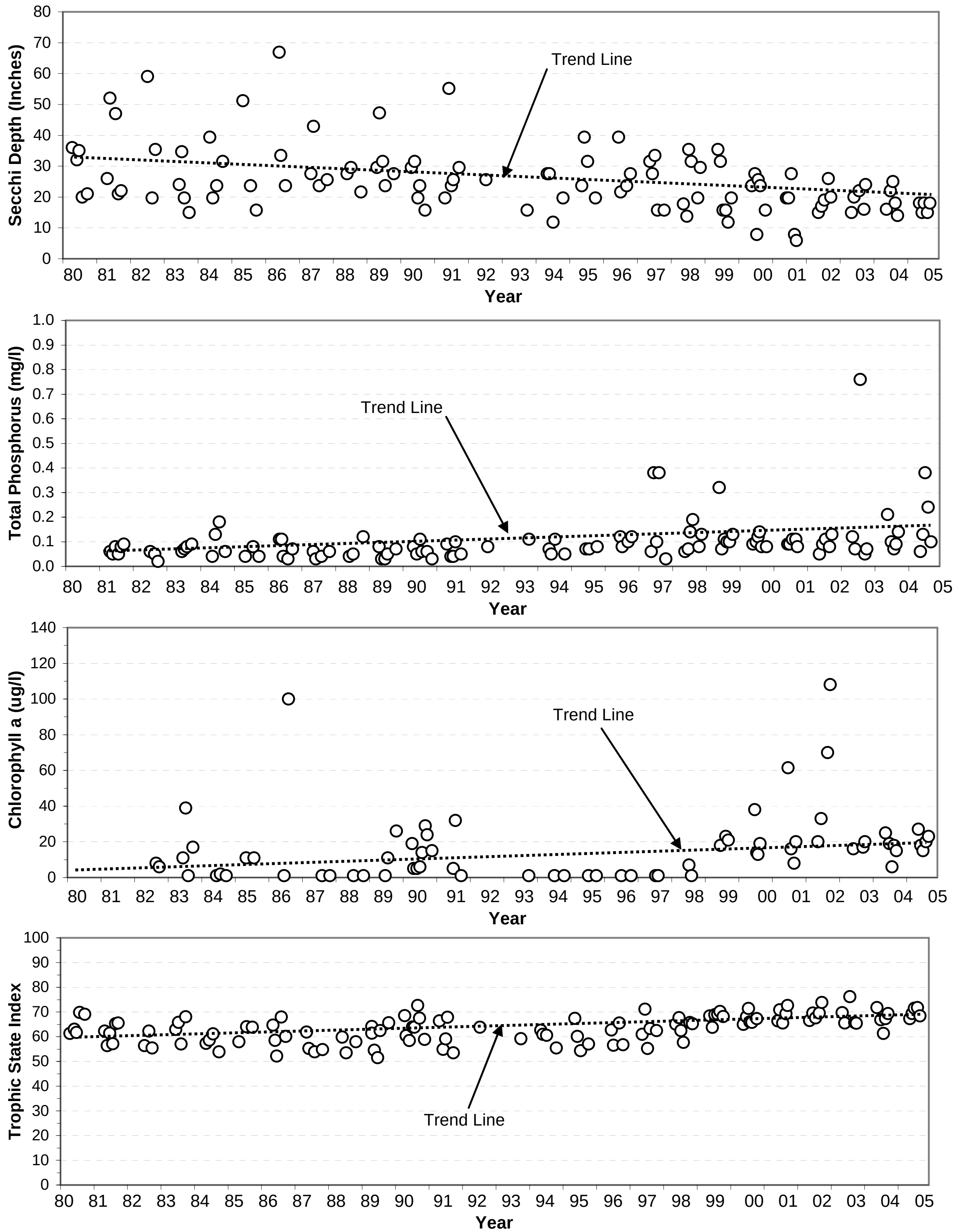


Plate 122. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Branched Oak Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

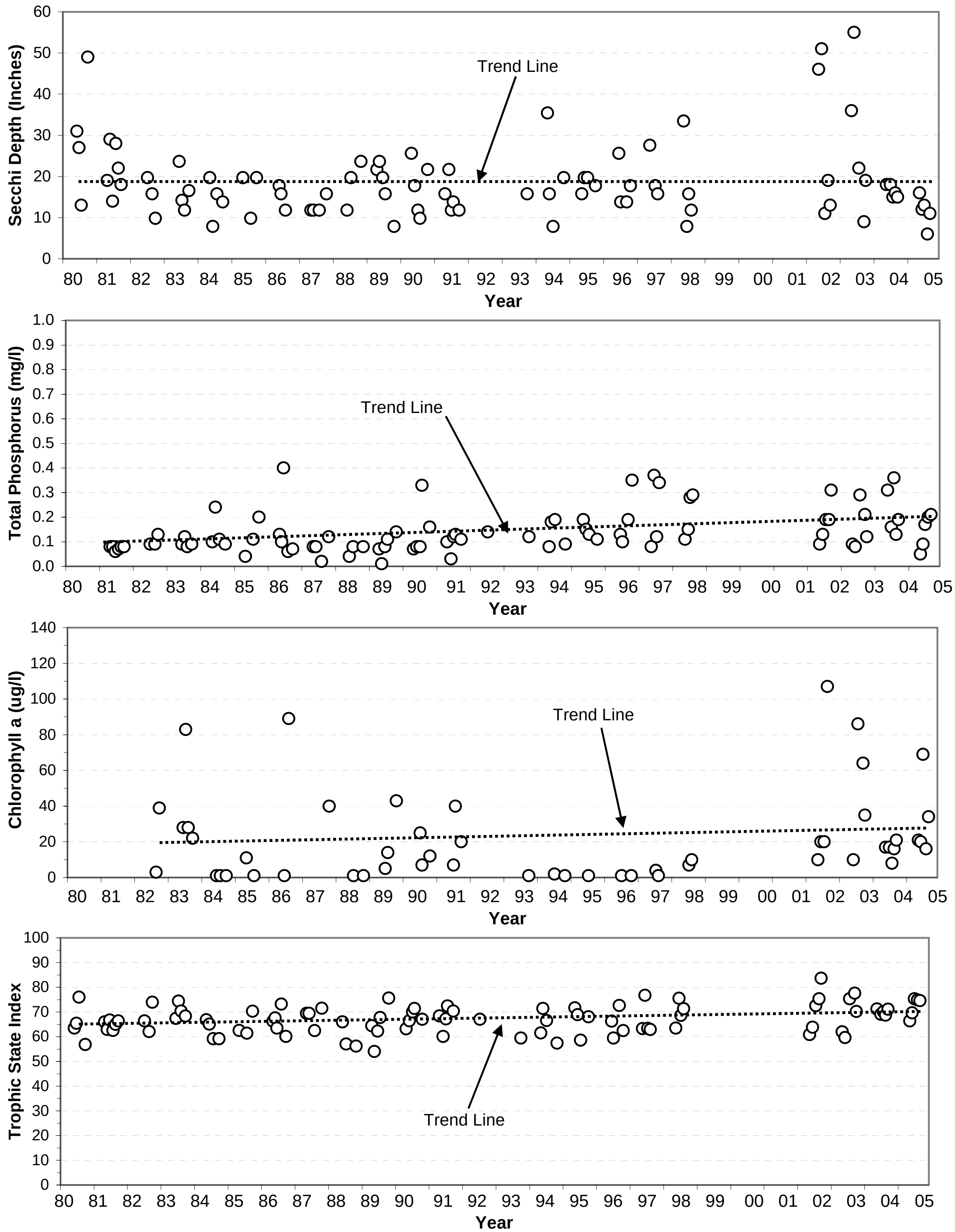


Plate 123. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Conestoga Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

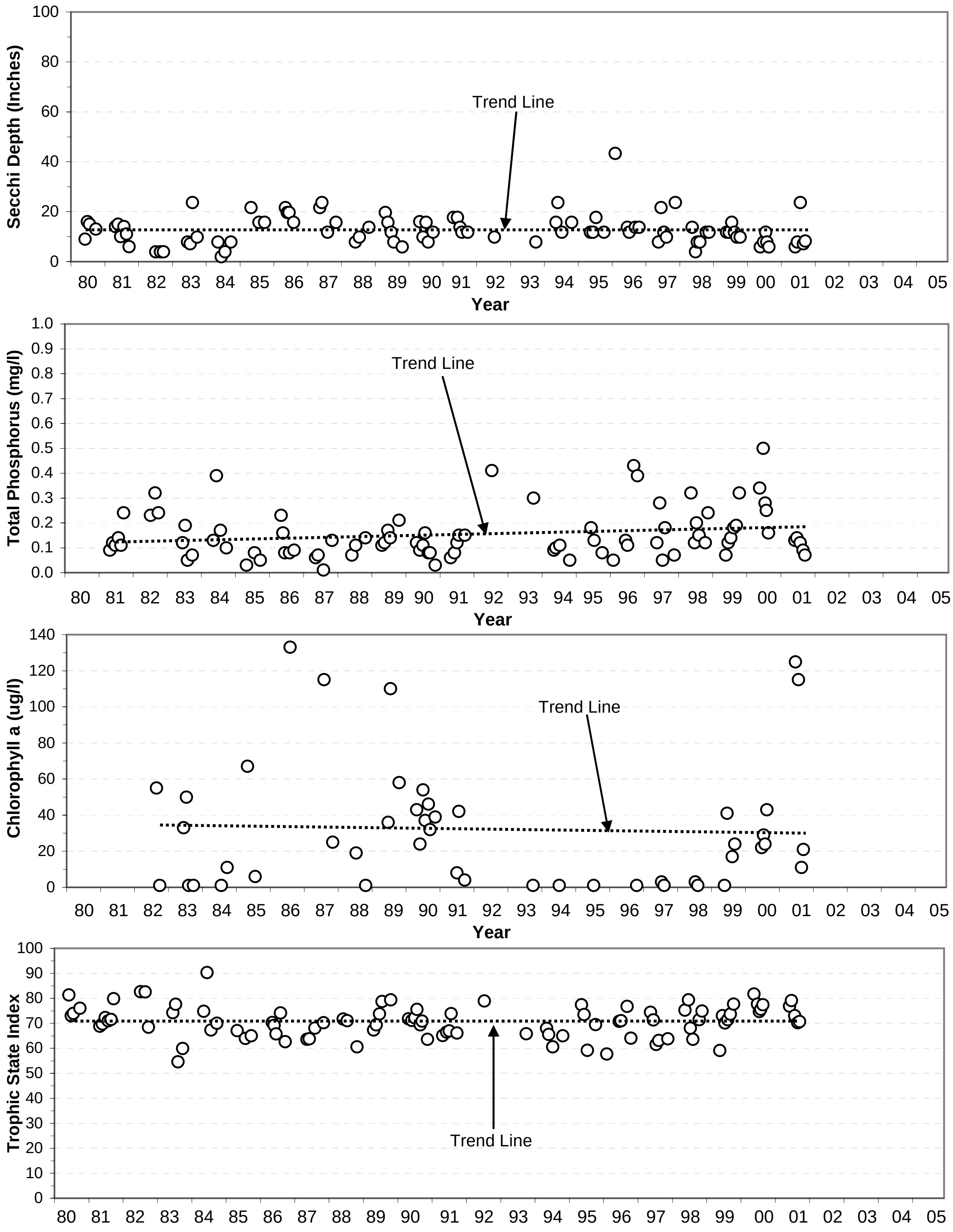


Plate 124. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Holmes Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

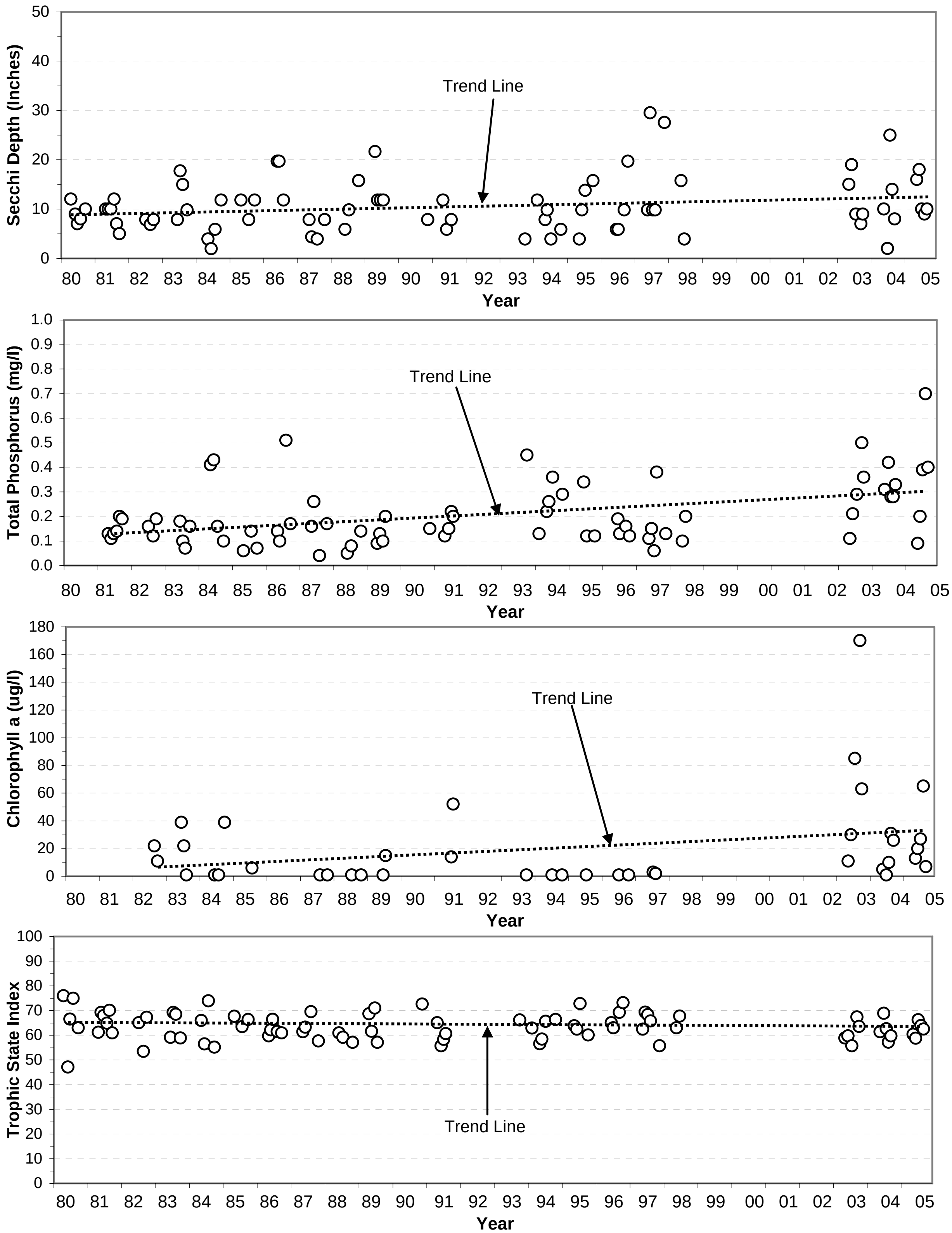


Plate 125. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Olive Creek Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

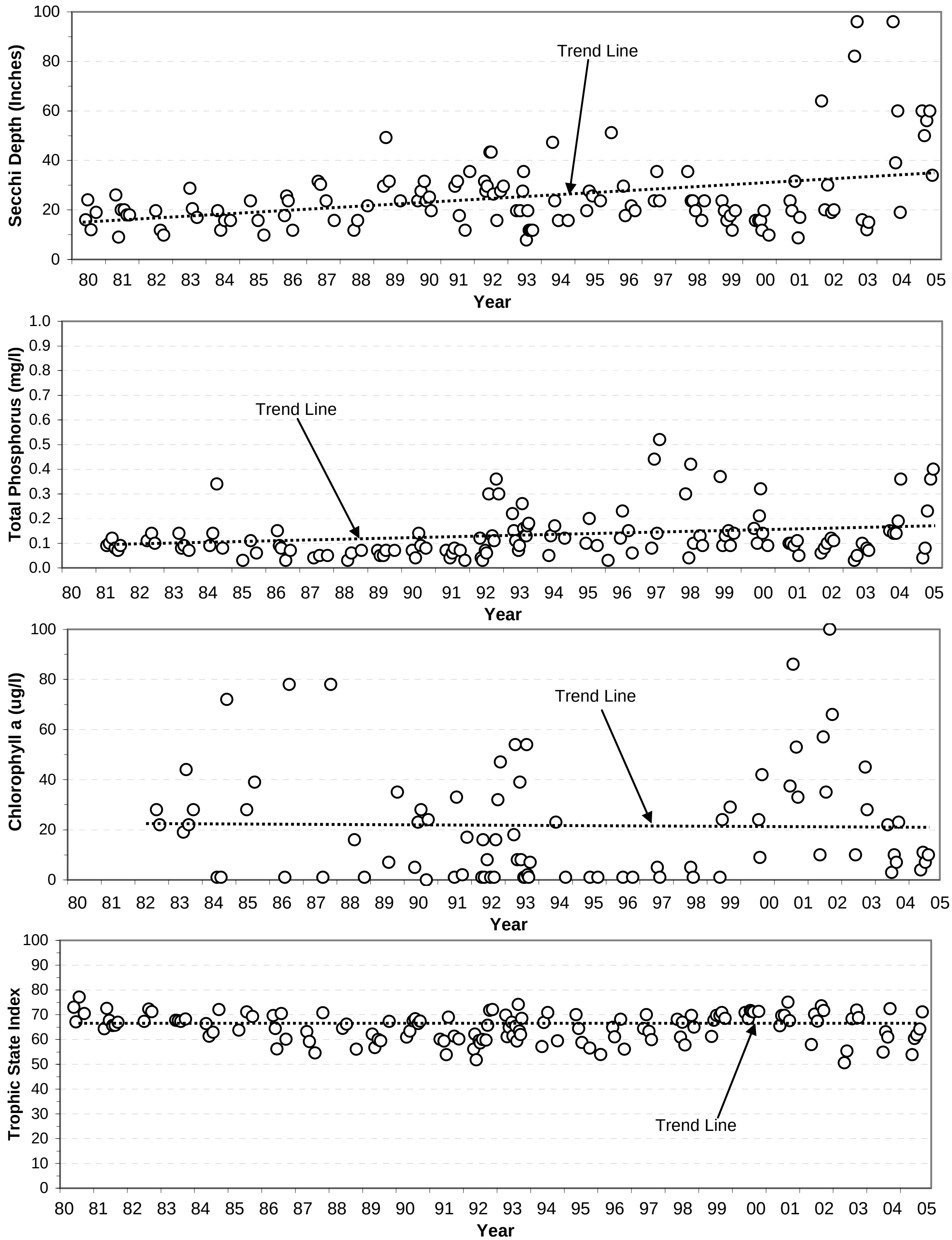


Plate 126. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Pawnee Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

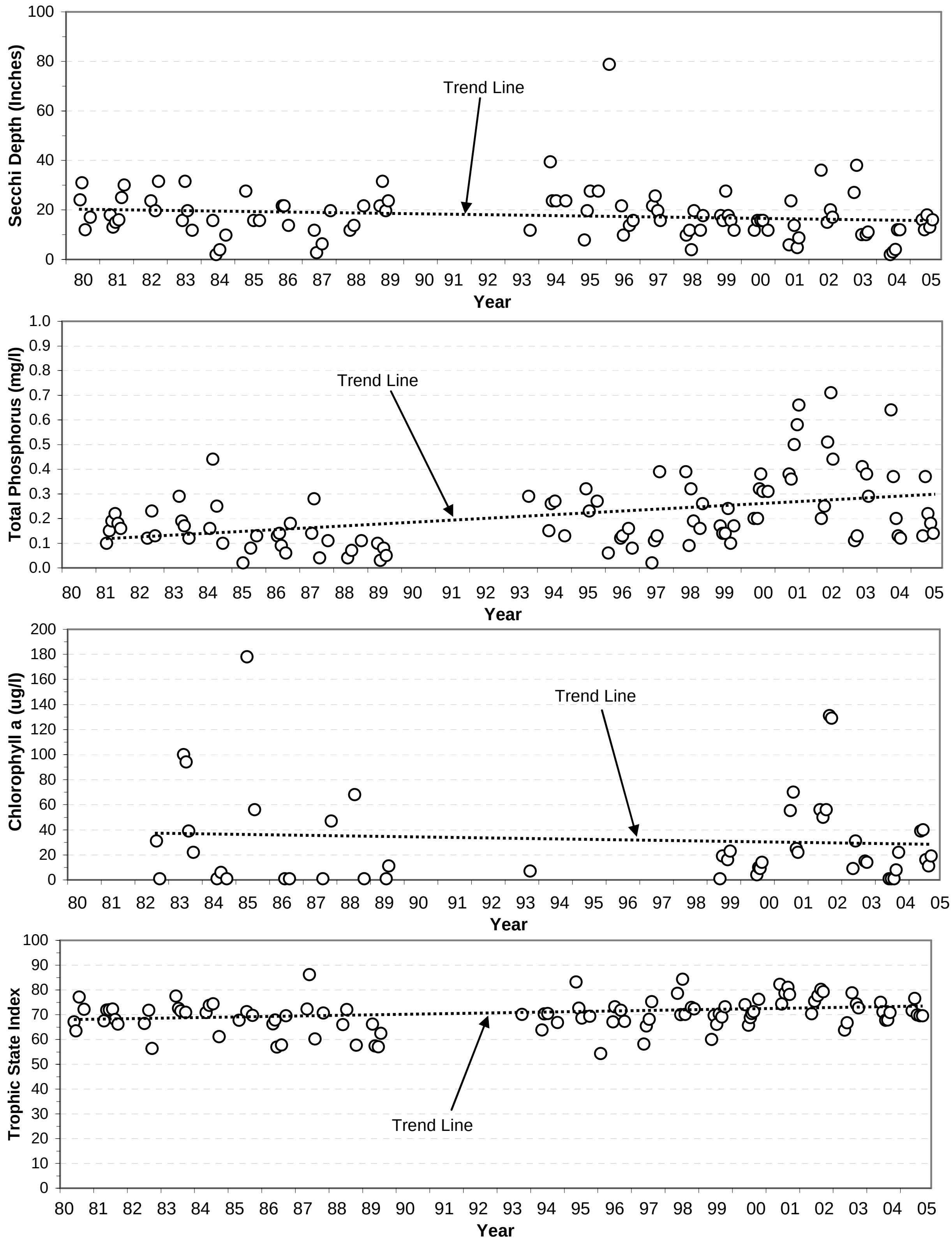


Plate 127. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Stagecoach Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

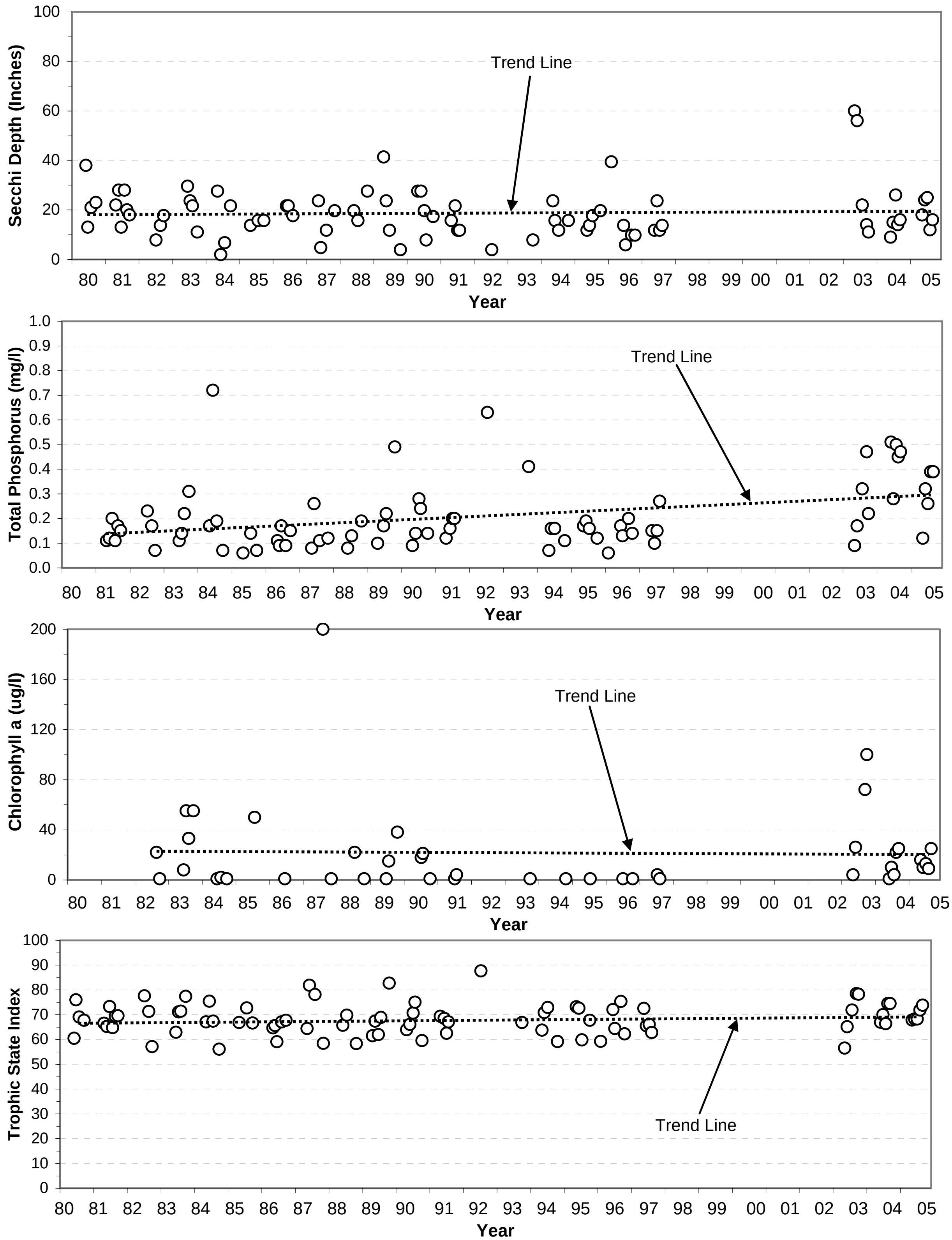


Plate 128. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Wagon Train Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

Plate 129. Summary of water quality conditions monitored in Bowman-Haley Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 4-year period 2001 through 2004. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	20	2752.0	2752.0	2749.7	2754.0	-----	-----	-----
Water Temperature (C)	0.1	248	17.2	18.1	6.4	28.0	29.4	0	0%
Dissolved Oxygen (mg/l)	0.1	244	7.7	7.6	3.3	14.8	$\geq$ 5.0	16	7%
Dissolved Oxygen (% Sat.)	0.1	244	83.8	84.3	39.0	188.5	-----	-----	-----
Specific Conductance (umho/cm)	1	248	2,275	2,223	1,204	3,041	-----	-----	-----
pH (S.U.)	0.1	214	8.7	8.7	7.9	9.2	$\geq$7.0 & $\leq$9.0	35	16%
Turbidity (NTUs)	0.1	85	20.8	16.3	6.6	88.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	85	330	317	196	379	-----	-----	-----
Secchi Depth (in.)	1	17	36	30	8	84	-----	-----	-----
Alkalinity, Total (mg/l)	7	34	321	328	208	396	-----	-----	-----
Ammonia, Total (mg/l)	0.01	24	0.35	0.31	n.d.	0.86	2.20(1,2), 0.55 (1,3)	0, 4	0%, 17%
Chlorophyll *a* (ug/l) – Field Probe	1	70	2	n.d.	n.d.	19	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	7	15	5	n.d.	71	-----	-----	-----
Hardness, Total (mg/l)	0.4	15	325	321	277	391	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	34	1.2	1.1	0.5	2.6	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	33	-----	0.10	n.d.	0.34	1	0	0%
Phosphorus, Total (mg/l)	0.01	34	0.09	0.09	0.03	0 17	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	32	-----	0.01	n.d.	0.11	-----	-----	-----
Suspended Solids, Total (mg/l)	4	34	16	15	n.d.	40	-----	-----	-----
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6(4)	0	0%
Arsenic, Total (ug/l)	3	3	-----	n.d.	n.d.	n.d.	340(2), 150(3), 50(4)	0	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4(4)	0	0%
Cadmium, Dissolved (ug/l)	0.5	2	-----	3	n.d.	6	16.8(2), 6.2(3)	0	0%
Chromium, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	4,686(2), 224(3)	0	0%
Copper, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	42(2), 25(3)	0	0%
Lead, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	360(2), 14(3)	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.7(2), 0 91(3), 0.05(4)	0	0%
Nickel, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	1,258(2), 140(3)	0	0%
Selenium, Total (ug/l)	2	1	-----	n.d.	n.d.	n.d.	20(2), 5(3), 50(4)	0	0%
Silver, Dissolved (ug/l)	1	1	-----	n.d.	n.d.	n.d.	30(2)	0	0%
Zinc, Total (ug/l)	3	3	8	8	8	9	322(2,3)	0	0%
Alachlor, Total (ug/l)	0.05	9	-----	n.d.	n.d.	n.d.	2(4)	0	0%
Atrazine, Total (ug/l)	0.05	9	-----	n.d.	n.d.	0.07	3(4)	0	0%
Metolachlor, Total (ug/l)	0.05	9	-----	n.d.	n.d.	0.10	40(4)	0	0%
Pesticide Scan (ug/l)***	0.05	3	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1) Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.7 and 18.1 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 321 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 130. Summary of water quality conditions monitored in Pipestem Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 4-year period 2001 through 2004. [Note: Results for water temperature, dissolved oxygen, conductivity, pH, turbidity, ORP, and chlorophyll *a* (Field Probe) are for water column profile measurements. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.]

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	20	1448.5	1445.1	1442.1	1474.2	-----	-----	-----
Water Temperature (C)	0.1	314	17.8	18.5	6.7	26.8	29.4	0	0%
Dissolved Oxygen (mg/l)	0.1	314	7.0	7.5	0.0	12.9	≥ 5.0	51	16%
Dissolved Oxygen (% Sat.)	0.1	314	75.6	82.6	0.0	142.3	-----	-----	-----
Specific Conductance (umho/cm)	1	314	1,174	1,204	364	1,438	-----	-----	-----
pH (S.U.)	0.1	275	8.3	8.4	6.7	9.4	≥7.0 & ≤9.0	14	5%
Turbidity (NTUs)	0.1	163	62.2	7.5	1.0	418.0	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	164	273	304	8	408	-----	-----	-----
Secchi Depth (in.)	1	20	60	46	20	138	-----	-----	-----
Alkalinity, Total (mg/l)	7	32	301	293	206	402	-----	-----	-----
Ammonia, Total (mg/l)	0.01	25	0.45	0.36	n.d.	1.40	3.38(1,2), 0.94 (1,3)	0, 2	0%, 8%
Chlorophyll *a* (ug/l) – Field Probe	1	104	15	11	n.d.	58	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	13	16	9	2	45	-----	-----	-----
Hardness, Total (mg/l)	0.4	14	478	498	274	545	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	34	1.3	1.2	0.8	2.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	34	-----	n.d.	n.d.	0.97	1	0	0%
Phosphorus, Total (mg/l)	0.01	34	0.40	0 39	0 13	0.84	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	31	0.30	0 31	n.d.	0.76	-----	-----	-----
Suspended Solids, Total (mg/l)	4	34	-----	6	n.d.	16	-----	-----	-----
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6(4)	0	0%
Arsenic, Total (ug/l)	3	3	-----	10	n.d.	11	340(2), 150(3), 50(4)	0	0%
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4(4)	0	0%
Cadmium, Dissolved (ug/l)	0.5	2	-----	3	n.d.	6	27.6(2), 8.7(3)	0	0%
Chromium, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	6,715(2), 321(3)	0	0%
Copper, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	64(2), 37(3)	0	0%
Iron, Total (ug/l)	40	3	191	181	145	247	-----	-----	-----
Lead, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	630(2), 25(3)	0	0%
Mercury, Total (ug/l)	0.02	2	-----	0.02	n.d.	0.04	1.7(2), 0 91(3), 0.05(4)	0	0%
Nickel, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	1,825(2), 203(3)	0	0%
Silver, Dissolved (ug/l)	1	1	-----	n.d.	n.d.	n.d.	64(2)	0	0%
Zinc, Total (ug/l)	3	3	-----	3	n.d.	7	467(2,3)	0	0%
Alachlor, Total (ug/l)	0.05	9	-----	n.d.	n.d.	n.d.	2(4)	0	0%
Atrazine, Total (ug/l)	0.05	9	0.10	0.08	n.d.	0.22	3(4)	0	0%
Metolachlor, Total (ug/l)	0.05	9	-----	n.d.	n.d.	n.d.	40(4)	0	0%
Pesticide Scan (ug/l)***	0.05	3	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1)Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.4 and 18.5 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Daily maximum criterion for domestic water supply.
Note: Many of Nebraska's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 498 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

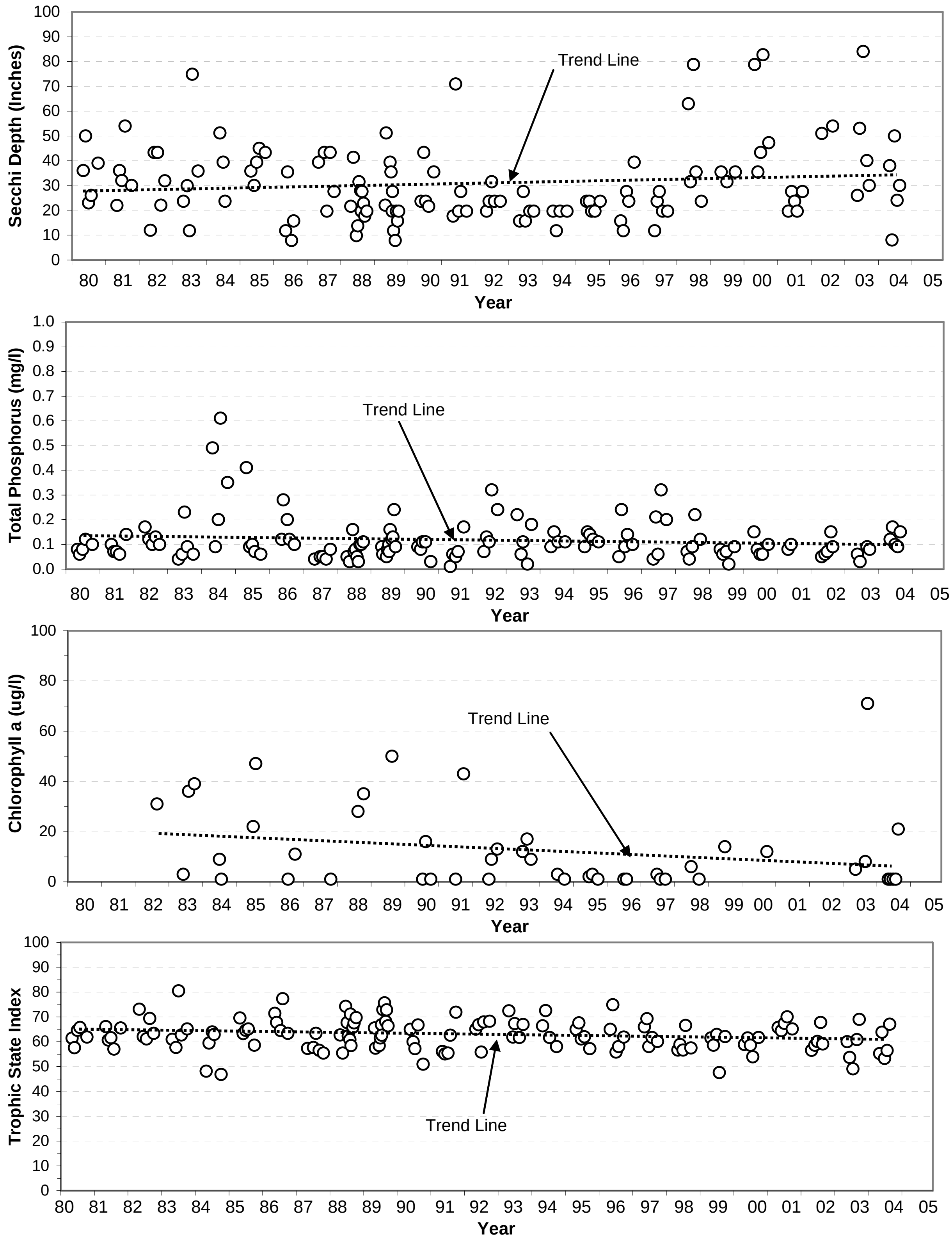


Plate 131. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Bowman-Haley Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

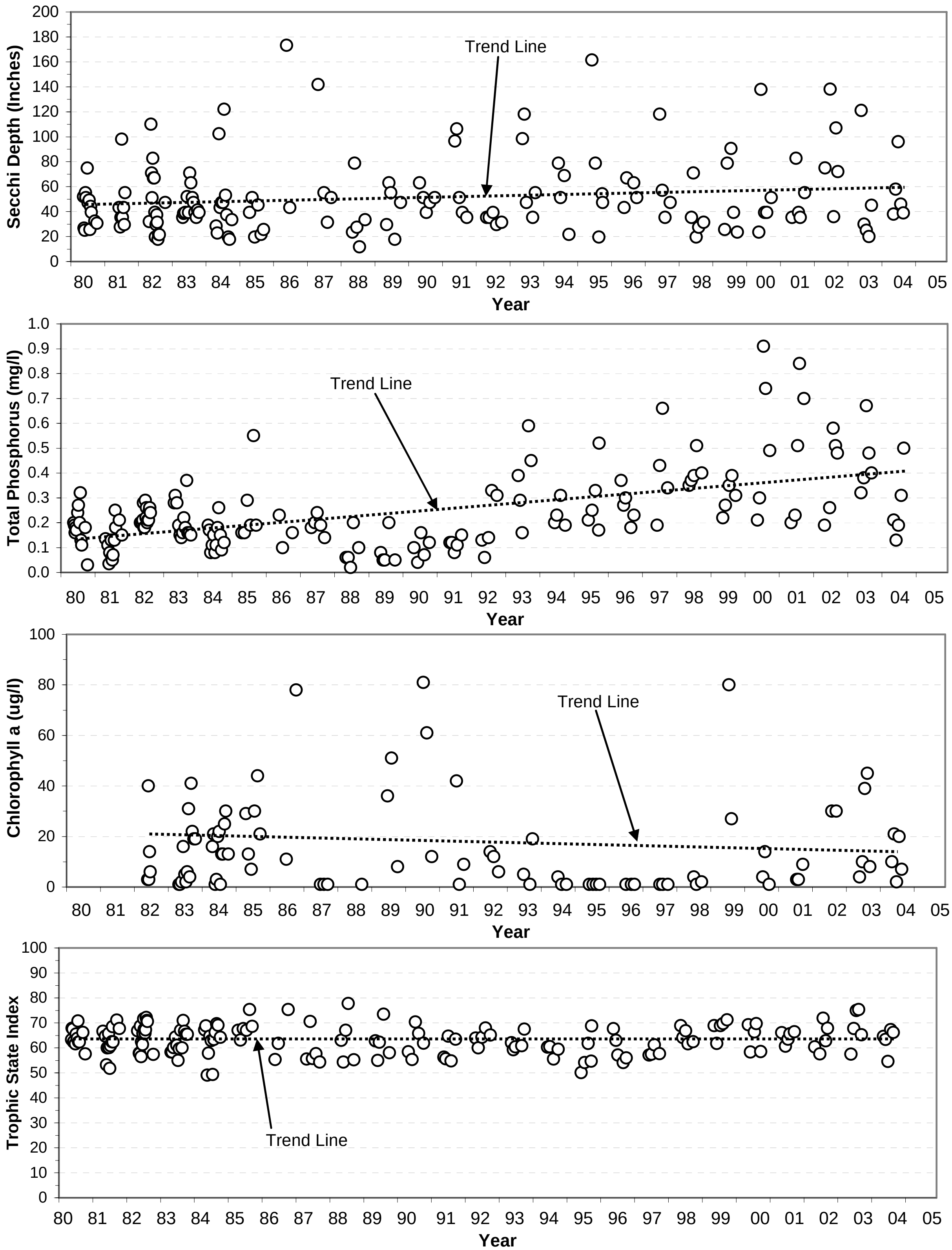


Plate 132. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Pipestem Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.

Plate 133. Summary of water quality conditions monitored in Cold Brook Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 3-year period 2001 through 2003.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	10	3582.9	3582.8	3582.4	3583.6	-----	-----	-----
Water Temperature (C)	0.1	181	20.6	21.1	11.3	26.0	18.3 23.8	135 45	75% 25%
Dissolved Oxygen (mg/l)	0.1	181	8.7	8.7	0.2	15.2	≥ 6.0 ≥ 7.0	9 12	5% 7%
Dissolved Oxygen (% Sat.)	0.1	181	105.3	107.2	2.2	177.3	-----	-----	-----
Specific Conductance (umho/cm)	1	174	498	478	441	746	-----	-----	-----
pH (S.U.)	0.1	181	8.2	8.3	7.3	8 5	≥6.6 & ≤8.6	0	0%
Turbidity (NTUs)	0.1	41	1.3	0.9	n.d.	4.7	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	41	348	317	143	441	-----	-----	-----
Secchi Depth (in.)	1	10	244	222	143	394	-----	-----	-----
Alkalinity, Total (mg/l)	7	16	161	159	141	187	-----	-----	-----
Ammonia, Total (mg/l)	0.01	9	-----	0.30	n.d.	1.00	1.77 [1,2], 0.82 [1,3]	0, 1	0%, 11%
Carbon, Total Organic (mg/l)	0.05	7	4.3	4.3	3.3	5.8	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	4	2	2	1	4	-----	-----	-----
Hardness, Total (mg/l)	0.4	11	240	234	215	301	-----	-----	-----
Iron, Total (ug/l)	40	1	96	96	96	96	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	17	-----	n.d.	n.d.	1.3	-----	-----	-----
Manganese, Total (ug/l)	1	1	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	17	-----	n.d.	n.d.	0.07	10[5]	0	0%
Phosphorus, Total (mg/l)	0.01	17	0.08	0.03	n.d.	0.73	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	17	-----	n.d.	n.d.	n.d.	-----	-----	-----
Sulfate (mg/l)	0.1	1	127	127	127	127	875[5]	0	0%
Suspended Solids, Total (mg/l)	4	17	-----	n.d.	n.d.	9	53[2], 30[3]	0	0%
Antimony, Dissolved (ug/l)	6	2	-----	n.d.	n.d.	n.d.	6[4]	0	0%
Arsenic, Total (ug/l)	3	1	6.7	6.7	6.7	6.7	340[2], 150[3], 0.018[4]	0/0/b.d.	0%/0%/b.d.
Beryllium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	4[4]	0	0%
Cadmium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	9.3[2], 1.9[3]	0	0%
Chromium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	34	1,101[2], 357[3]	0	0%
Copper, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	38[2], 23[3], 1,300[4]	0	0%
Lead, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	160[2], 6.3[3]	0	0%
Mercury, Dissolved (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	1.4[2]	0	0%
Mercury, Total (ug/l)	0.02	1	-----	n.d.	n.d.	n.d.	0.012[3]	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	2	-----	n.d.	n.d.	n.d.	2,906[2], 323[3], 610[4]	0	0%
Selenium, Total (ug/l)	4	2	-----	n.d.	n.d.	n.d.	4.6[3], 170[4]	0	0%
Silver, Dissolved (ug/l)	1	2	-----	n.d.	n.d.	n.d.	14 9[2]	0	0%
Zinc, Total (ug/l)	3	1	3	3	3	3	235[2], 215[3] 7,400[4]	0	0%
Alachlor, Total (ug/l)	0.05	5	-----	n.d.	n.d.	0.08	-----	-----	-----
Atrazine, Total (ug/l)	0.05	5	-----	n.d.	n.d.	0.12	-----	-----	-----
Metolachlor, Total (ug/l)	0.05	5	-----	n.d.	n.d.	0.07	-----	-----	-----
Pesticide Scan (ug/l)***	0.05	1	-----	n.d.	n.d.	n.d.	****	0	0%

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

** [1]Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.3 and 21.1 respectively.
[2] Acute criterion for aquatic life.
[3] Chronic criterion for aquatic life.
[4] Human health criterion for surface waters.
[5] Daily maximum criterion for domestic water supply.
Note: Many South Dakota's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 234 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

Plate 134. Summary of water quality conditions monitored in Cottonwood Springs Reservoir at the near-dam, deepwater ambient monitoring location from May to September during the 2-year period 2001 through 2002.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	6	3865.8	3865.3	3863.8	3868.8	-----	-----	-----
Water Temperature (C)	0.1	85	20.0	21.0	13.9	26.0	26.6	0	0%
Dissolved Oxygen (mg/l)	0.1	85	6.9	7.4	0.2	8.9	≥ 5.0 ≥ 6.0	9 13	11% 15%
Dissolved Oxygen (% Sat.)	0.1	85	87.3	89.4	2.0	118.6	-----	-----	-----
Specific Conductance (umho/cm)	1	85	1,698	1,750	905	1,829	-----	-----	-----
pH (S.U.)	0.1	85	8.0	8.0	7.4	8.2	≥6.5 & ≤9.0	0	0%
Turbidity (NTUs) – Lab Determined	0.1	6	2.7	2.5	2.0	4.0	-----	-----	-----
Secchi Depth (in.)	1	6	248	238	146	394	-----	-----	-----
Alkalinity, Total (mg/l)	7	10	88	85	51	158	-----	-----	-----
Ammonia, Total (mg/l)	0.01	2	-----	n.d.	n.d.	n.d.	8.41 (1,2),1.57 (1,3)	0	0%
Carbon, Total Organic (mg/l)	0.05	8	7.2	7.3	3.8	8.6	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	2	997	997	366	1,628	1,750(5)	0	0%
Hardness, Total (mg/l)	0.4	8	1,025	1,109	290	1,233	-----	-----	-----
Iron, Total (ug/l)	40	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	10	-----	0.1	n.d.	0.3	-----	-----	-----
Manganese, Total (ug/l)	1	2	-----	47	n.d.	94	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	10	-----	n.d.	n.d.	0.09	10(5)	0	0%
Phosphorus, Total (mg/l)	0.01	10	0.03	0.03	n.d.	0.05	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	10	-----	n.d.	n.d.	n.d.	-----	-----	-----
Sulfate (mg/l)	0.1	2	498	498	149	846	875(5)	0	0%
Suspended Solids, Total (mg/l)	4	10	-----	n.d.	n.d.	6	158(2), 90(3)	0	0%
Antimony, Dissolved (ug/l)	6	1	-----	n.d.	n.d.	n.d.	6(4)	0	0%
Arsenic, Total (ug/l)	3	2	-----	3	n.d.	5	340(2), 150(3), 0.018(4)	0/0/b.d.	0%/0%/b.d.
Beryllium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	4(4)	0	0%
Cadmium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	3.0	49.9(2), 6.1(3)	0	0%
Chromium, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	3,937(2), 1,277(3)	0	0%
Copper, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	164(2), 89(3), 1,300(4)	0	0%
Lead, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	766(2), 30(3)	0	0%
Mercury, Dissolved (ug/l)	0.02	1	-----	n.d.	n.d.	n.d.	1.4(2)	0	0%
Mercury, Total (ug/l)	0.02	1	-----	n.d.	n.d.	n.d.	0.012(3)	b.d.	b.d.
Nickel, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	10,837(2), 1,203(3), 610(4)	0	0%
Selenium, Total (ug/l)	4	1	-----	n.d.	n.d.	n.d.	4.6(3), 170(4)	0	0%
Silver, Dissolved (ug/l)	1	1	-----	n.d.	n.d.	n.d.	216(2)	0	0%
Zinc, Total (ug/l)	3	2	-----	3	n.d.	5	879(2), 803(3) 7,400(4)	0	0%
Alachlor, Total (ug/l)	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Metolachlor, Total (ug/l)	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Below detection limit.

* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean is not reported. The mean value reported for pH is an arithmetic mean based on measured values (i.e , log conversion of logarithmic pH values was not done to calculate mean).

** (1)Total ammonia criteria pH and temperature dependent. Criteria listed are for median pH and temperature values of 8.0 and 21.0 respectively.
(2) Acute criterion for aquatic life.
(3) Chronic criterion for aquatic life.
(4) Human health criterion for surface waters.
(5) Daily maximum criterion for domestic water supply.
Note: Many South Dakota's WQS criteria for metals are hardness based. As appropriate, listed criteria were calculated using the median hardness of 1,109 mg/l.

*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

**** Some pesticides don't have water quality standards criteria defined, and for those pesticides that have criteria, the criteria vary.

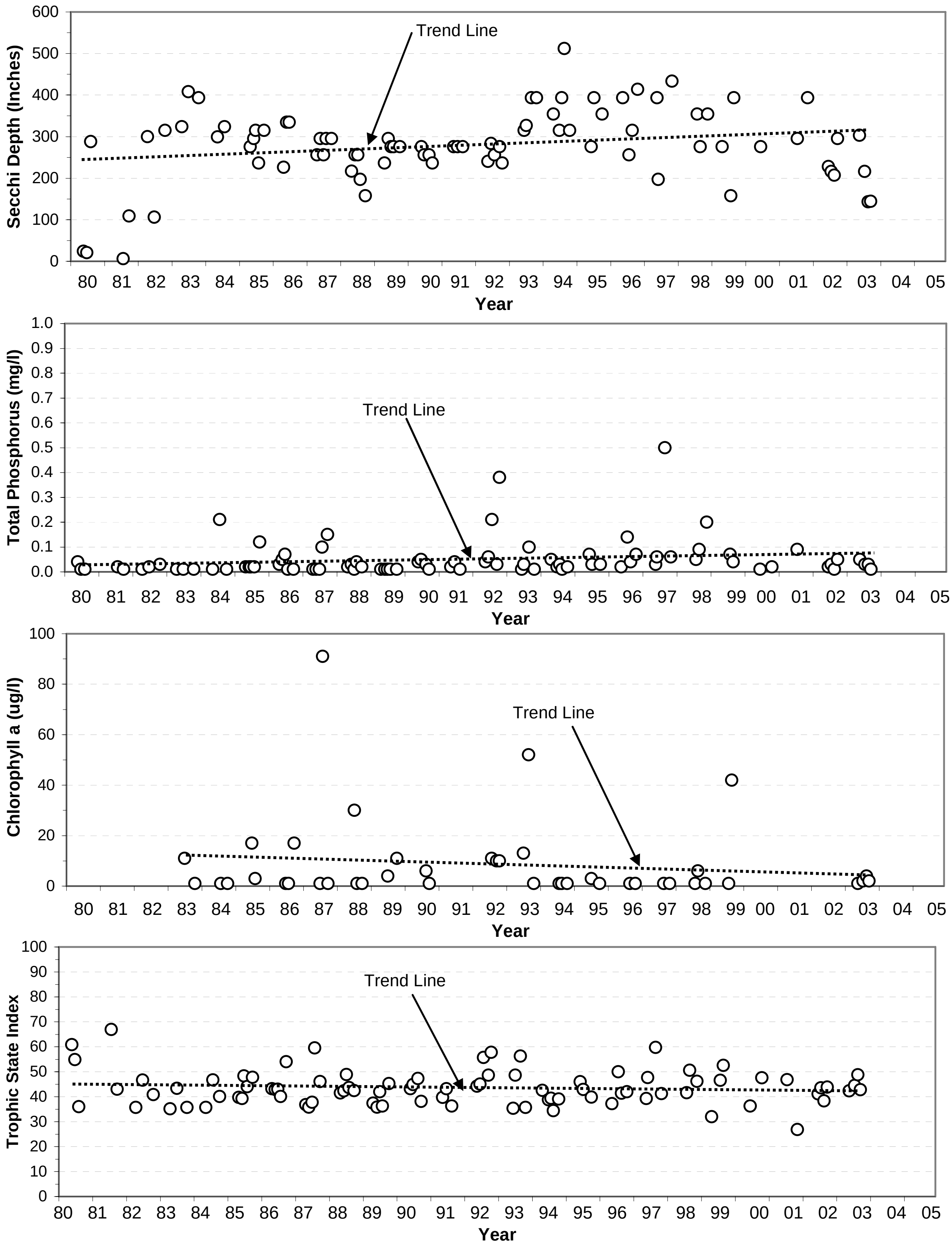


Plate 135. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and TSI monitored in Cold Brook Reservoir at the near-dam, ambient site over the 26-year period of 1980 through 2005.